Engine No. 999, New York Central & Hudson River R. R.
Record 102.8 Miles per Hour.

ONE THOUSAND POINTERS

FOR

MACHINISTS AND ENGINEERS

BY

CHAS. McSHANE,
(PRACTICAL MACHINIST.)

ILLUSTRATED.

TWENTY-NINTH THOUSAND.

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INDORSEMENT.

PROGRESSIVE LODGE No. 126,
INTERNATIONAL ASSOCIATION OF MACHINISTS.

Chicago, Ill., January 18, 1896.

At the regular meeting of Progressive Lodge No. 126, held January 17, 1896, the following resolutions were passed:

Whereas, Brother Charles McShane, a member of this Lodge, has written a mechanical work entitled "One Thousand Pointers for Machinists and Apprentice Boys," which he has dedicated to our order; and

Whereas, We knowing Brother McShane to be a modern, progressive machinist of wide experience and extraordinary ability, thoroughly competent to write such a treatise;

Resolved, therefore, That we, believing his purpose laudable, heartily indorse his work, and most cheerfully commend it to the brothers of our order.

JAMES DONEGAN,
Recording Secretary.

JAMES ADAMS,
Master Machinist.

PREFACE.

The necessity for a revision and enlargement of this work is due to the approbation bestowed upon it by Machinists, and repeated requests from Engineers and Firemen that Air Brakes, Break Downs, Blows and Pounds, of a locomotive be treated with its construction. This I have endeavored to do, the best authorities on each subject being frequently consulted; how far my execution has corresponded with my design is for the reader to decide.

Believing that the language of a mechanical book should be understood rather than admired, I have made no attempt at what is called fine writing, but have used as plain and familiar language as the exceedingly technical character of the subject would permit.

The pleasure is now afforded me of extending public thanks to Mr. J. G. A. Meyer; Mr. Clinton B. Conger; Mr. Wm. F. M. Goss; and Mr. J. P. Hine, who have each contributed articles in the preparation of the work; also to my friend Mr. John C. White, who has rendered valuable assistance, and to the technical journals, railway companies and manufacturers who have so kindly aided me in this which has proved an arduous task.

The book is now respectfully submitted, but not without consciousness of its many imperfections, yet with the hope that it may serve as a stepping stone to a more thorough and comprehensive knowledge of the locomotive.

C. McS.

Chicago, August 1, 1896.

PREFACE TO THE FIRST EDITION.

In presenting this work to the mechanics of America it may not be improper to state the reasons which induced its undertaking, and the objects sought to be accomplished by it. There have been many good mechanical works published, but none practical that we can use as a guide for our every-day requirements. The design of this work is to present in condensed form everything essential, and the most progressive and modern methods of performing work in the various branches of our trade, locomotive construction being the special feature. There is nothing experimental or visionary in this book. To the machinist it offers a means of easy and ready reference, while to the apprentice it is presented as a guide.

It is also intended to supply an educational want which is becoming more and more imperative as the modes and changes in mechanism grow more complex, intricate and extended. The plainest language has been used in this work, so that men of moderate education will understand it. There is no one subject in this book to which I desire to call special attention, as possessing superior merit over any other part of it. As a whole, it is most humbly submitted and respectfully dedicated to the International Association of Machinists, with the ardent hope that it may be found useful in lessening their labors and increasing the value of their services, and thus perform its part in aiding a vocation for whom personally, and as a member of the order, I have the highest regard and esteem.

Respectfully yours,

CHAS. McSHANE.

Chicago, January 31st, 1896.

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BRIEF HISTORY OF THE LOCOMOTIVE.

The word locomotive is derived from the two Latin words locus, which signifies a place, and motum, which means to move. It is therefore a well constructed word, which signifies something that moves from one location to another. The Encyclopedia Britannica records the use of steam for heating purposes back to the year 150 B. C. But to James Watt, more than any other man, is due the honor of first controlling and utilizing steam for power, although Newcomer and others had used steam for power before Watt. The first steam engine was built by Isaac Newton, in 1680. It consisted of a spherical boiler mounted on a carriage and the intended propulsion was through the force of steam against the atmosphere, which proved a complete failure, for it never moved. The first self-moving steam engine was mounted on a carriage for roadways; it was built by Nicholas Cagnot, in France in 1769. But to Trevithick of England is due the honor of first applying steam to railways. His engine was called the "Trevithick," and was first run on the Merthyr Tydvil Tramway in South Wales, February 1, 1804. The first locomotive built in America was constructed for roadways in 1790, by Nathan Read of Salem, Mass. The first locomotive to run on rails in America was the "Tom Thumb," built by Peter Cooper of New York, in 1829, and was run before any locomotive was imported to this country. The first locomotive imported to this country was the "Stourbridge Lion," in 1829; it was built by Foster & Rastrick, of England. Various forms of valve gear were in use in those early days, but hook motion predominated. Mr. William T. James, of New York, used a crude form of link motion in 1831, but the Stephenson link which we use to-day was invented by Mr. William Howe, an employe of Robert Stephenson & Co., of Newcastle, England, in 1842, but hook motion remained in use many years afterward. Those who have never seen hook motion can see it on "Old Ironside," now on exhibition at the Field Columbian Exposition, Chicago. Several other forms of valve gear have since been invented, but to-day link motion is the standard valve gear on most every locomotive throughout the world. Many remarkable engines were built about the

middle of this century by Stephenson, Ericsson, James, Cooper Rogers and others, but they do not compare with our modern locomotives as our builders have the advantage of 50 years of recorded experience in locomotive construction. American engines are the fastest and most powerful locomotives in the world, so we have written a special chapter on Modern Locomotives and Fast Runs, illustrating several of the best. (Page 264.) A freak in locomotive construction which attracted considerable attention at the World's Fair at Chicago in 1893 was the "James T. Toleman," which was an untried experiment built by Mr. Winby, of England, to haul heavy fast trains in America. She is a 40-ton engine with four cylinders, 17x22" and 16½x24"; all high pressure, and four driving wheels 7', 6" in diameter. Two of the cylinders are outside and connected to the rear driving wheels; and two are inside connected to the forward driving wheels. The steam distribution for one pair of cylinders is by the ordinary shifting link and for the other pair by the Joy Valve Gear. The two pair of driving wheels are not coupled, the cylinders for each pair doing their work independently of the other pair; the reverse lever is common to all the cylinders. After the Fair she was tried on the Chicago, Milwaukee & St. Paul Ry. Co., where she proved a complete failure, and she is now quietly resting (and rusting) on a side track at the Milwaukee shops. The smallest locomotive built for actual service of which there is any record, was built in Belgium, and only weighed 2,420 pounds. The cylinders were 3⅛x6¼ inches, and diameter of driving wheels 15¼ inches. This locomotive, together with a car and one mile of portable track, was presented to the Sultan of Morocco, by the King of Belgium to be used in the gardens of the palace. This imperial toy had necessarily to be carried in pieces from the port of landing to the Capital by the primitive mode of freight transportation, the pack-saddle, the heaviest parts, the boiler and lower frame, weighing only 660 pounds. The heaviest locomotive ever constructed is owned by the Southern Pacific Railway; it is a 12-wheeled consolidation engine, and weighs 266,333 pounds.

This work does not treat upon electricity, but a history of the locomotive would be incomplete without reference to the electric locomotive now used on the B. & O. Ry. Therefore, we have shown a view of the engine, giving its principal dimensions and performances on page 265. While it is probable that electric locomotives will eventually supersede the steam engine, the development of electricity as applied to railways is yet in a crude form, and it will require many years to retire the steam locomotive from all kinds of service.

THE SLIDE VALVE.

INVENTION OF.

The slide valve in a crude form, was invented by Matthew Murray, of Leeds, England, toward the end of the eighteenth century. It was subsequently improved by James Watt, but the long D slide valve which we use at the present day, is credited to Murdock, an assistant of Watt. It came into general use with the introduction of the locomotive, although Oliver Eames, of Philadelphia, appears to have perceived its actual value, for he applied it to engines of his own build years before the locomotive era. But it was upon the locomotive that it clearly demonstrated its real value, its simplicity of construction and its durability together with the high speed at which it could be worked at once commended it to the designers of locomotives in those days, and although repeated efforts have been made to displace it, it is still employed in one or other of the many forms on the great majority of engines.

REQUIREMENTS OF THE SLIDE VALVE.

All slide valves must be capable of fulfilling the three following conditions, and if a slide valve cannot do this the engine will not work satisfactorily.

1st. Steam must be admitted into the cylinder at one end only at the same time.

2nd. It should permit the steam to escape from one end of the cylinder, at least as soon as it is admitted into the other end.

3rd. It should cover the steam ports so as not to allow steam to escape from the steam chest into the exhaust ports.

TECHNICAL DEFINITION OF LEAD, LAP, ETC.

When the amount of outside or inside lap a valve has is mentioned, it implies that amount on each side of the valve.

The two outside edges of the valve are called the steam edges, and the two inside edges are called the exhaust edges.

"Outside lap," frequently called steam lap, is that portion of the valve which overlaps the steam ports, when the valve stands central upon the valve seat, it is that part of the valve marked L and indicated by the space between lines A and B in Fig. 1.

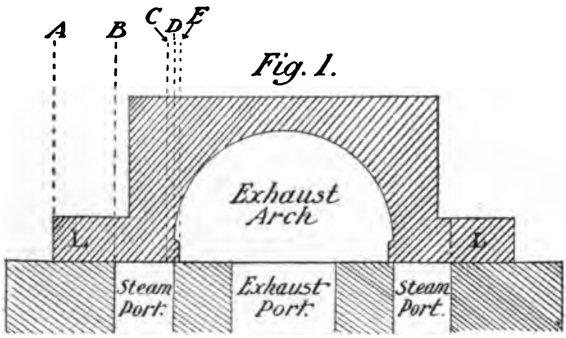
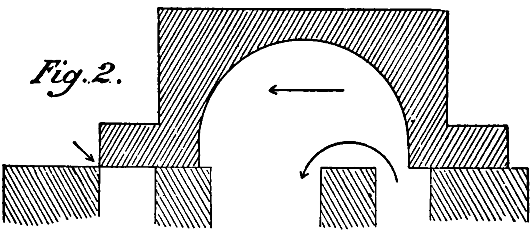


Fig. 1.

"Inside lap" of a valve, sometimes called exhaust lap, exhaust cover, and inside cover, is that portion of the valve which overlaps the two bridges of the valve seat, when the valve stands central upon the seat; as shown in Fig. 1, and indicated by the space between lines D and E.

Fig. 2.



"Inside clearance," sometimes called negative exhaust lap, or inside lead or exhaust lead, is no portion of the valve; but is the space between the inside edges of the exhaust arch and the bridges when the valve stands central upon the valve seat. As indicated by the space between lines C and D in Fig. 1. The term inside clearance means that amount on each side.

"Cut-off" means the cutting off of live steam before the piston has completed its stroke, and thereby utilizing the expansive force of steam. The point of cut-off is reached when the steam edge of the valve completely closes the steam port, as shown in Fig. 2.

"Compression" means the cutting off of the exhaust steam before the piston has completed its stroke, to be compressed by

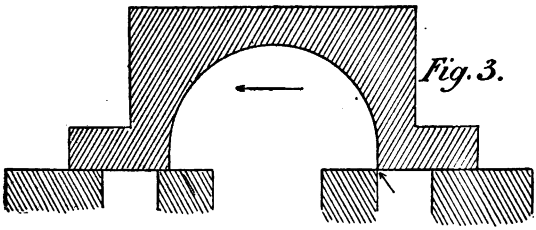


Fig. 3.

the advancing piston, and its pressure increased to arrest the motion of the reciprocating parts. The point at which compression begins, is reached, when the inside, or exhaust edge of the valve, has completely closed the steam port and thereby cut-off the exhaust steam, as shown in Fig. 3.

"Release or Exhaust" means the release of the expanded steam from the cylinder, this point is reached when the inside or exhaust edge of the valve opens the port and permits the

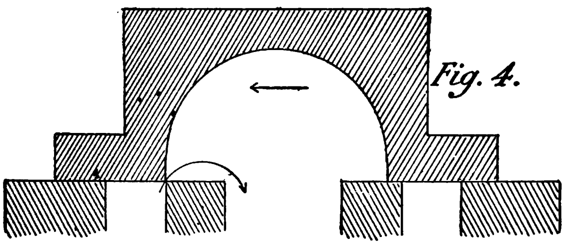


Fig. 4.

steam to escape, as shown in Fig. 4, it is at this point the engine exhausts or puffs.

"Expansion" means the expanding of the steam encased in the cylinder, and its time or duration lasts from the point of cut off, Fig. 2, to the point of release or exhaust. (See Fig. 4.) Therefore the space the valve travels during expansion equals the total of the outside and inside lap of the valve.

"Lead," sometimes called steam lead, is no portion of the valve, it means the width of the opening of the steam port to admit steam into the cylinder when the piston is at the beginning of its stroke. It is indicated by the letter L in Fig. 5.

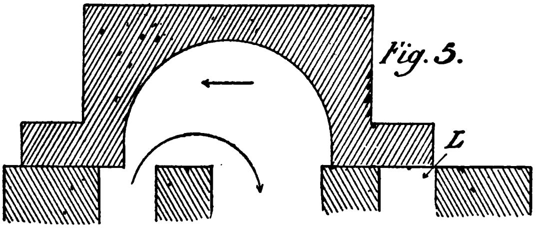


Fig. 5.

"Over travel" is the distance the steam edge of the valve travels after the steam port is wide open, as indicated by space between lines A and B in Fig. 6.

"Travel," stroke, or throw of the valve is the linear distance through which any part of it travels.

"Clearance" is all the waste space between the valve and the piston when the piston is at the beginning of a stroke.

"Seal" is an overlapping of the steam edges of the valve to prevent leakage.

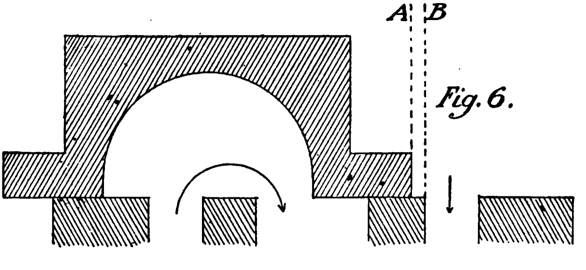


Fig. 6.

Now that the reader understands the technical definition of the terms lap, lead, etc., a further explanation of the reasons why the valve is given these functions becomes necessary.

THE EFFECT OF LAP.

When only one slide-valve is used for the whole distribution of steam in one cylinder, as in locomotives, and the valve has

no lap, we may justly name the form of such a valve a primitive one, because valves without lap, or only a trifling amount, about 1-16 of an inch, were used in locomotives years ago, when the great necessity for an early and liberal exhaustion was not so well understood as at present, the chief aim then being to secure a timely and free admission of steam. Such valves, as we have stated before, will admit steam during the whole length of the stroke, or, in other words, follow full stroke, and release the steam in one end of the cylinder at the same moment, or nearly so, that the steam is admitted into the other end; this is certainly no profitable way of using steam, for the following reasons: The process of exhausting steam requires time, and therefore the release of steam should begin in one end of the cylinder some time before steam is admitted into the other end, or, we may say, the steam which is pushing the piston ahead should be released before the end of the stroke has been reached. This cannot be accomplished with a valve having no lap, and, consequently, when such a valve is used, there will not be sufficient time for the exhausting of steam, thus causing considerable back pressure in the cylinder. In order to secure an early exhaust, lap was introduced; first ⅜ of an inch lap was adopted, then ½ of an inch. But it soon became apparent that working the steam expansively (a result of lap, besides gaining an early exhaust) additional economy in fuel was obtained, hence the lap was again increased until it became ⅞ of an inch, and, in some cases, 1 inch, and even more than this. At the present time the lap of a valve in ordinary locomotives with 17x24 inches, or 18x24 inch cylinders is ⅞ to 1 inch, and, in a few cases slightly exceeding this. From these remarks we may justly conclude, that in these days, the purpose of giving lap to the valve, is to cause it to cut off steam at certain parts of the stroke of the piston, so that during the remaining portion of the stroke the piston is moved by the expansion of the steam. When steam is used in this manner, it is said to be used expansively.

WHY THE VALVE IS GIVEN LEAD.

The valve is given lead in order that the steamport will have a greater opening at the beginning of the piston's stroke, when it is mostly needed, it also permits of an earlier cut-off, increases compression, and helps to fill the waste volume of clearance.

CONSTRUCTION OF THE VALVE SEAT, AND VALVE.

As the construction of a valve depends entirely upon the proportions of the valve seat, before we enter upon a more thorough study of the valve we will first call the reader's attention to a few things to be considered when designing a valve, and afterward the various effects of lead, lap, travel, etc. We will then study the relative positions of the valve and piston and explain the correct manner to design a valve seat, the valve face and parts.

THE VALVE SEAT.

Area of Steam Ports.

The area of the steam port depends largely upon the speed and other requirements of the engine, and the dimensions of its other parts. Its area is next in importance to the cut-off, and it is considered the base from which all other dimensions are derived when proportioning a valve face and its seat. The higher the speed required the larger the port is made in order to secure a free admission and release. Upon locomotives the area of the steam port varies from one eighth to one tenth the area of the piston. The proportions given in the following tables have been found to give good results. To find the proper area for a steam port multiply the area of the piston in square inches by the number opposite to the given piston speed.

Speed of Piston in feet per minute.	Number to multiply by.
100	0.02
200	0.04
300	0.06
400	0.07
500	0.09
600	0.10
700	0.12
800	0.14
900	0.15
1000	0.17

Another rule for determining the area of the steam ports for locomotives is given as follows: Multiply the square of the diameter of the cylinder by .078. The ports are usually

made a length equal to the diameter of the cylinder, but the longer the port can be made the better the results it will give; as it gives a greater opening for admission and release, reduces the travel necessary for a full port opening and diminishes the area on the back of the valve, thereby requiring less power to move the valve.

THE BRIDGES.

For the same reason the steam ports are made narrow, viz., to reduce the pressure required to move the valve. The bridges should also be made as narrow as possible, but they must be made strong enough to resist the highest pressure, therefore their proper width is considered equal to the thickness of the walls of the cylinder. Although they are usually made a little wider, yet the face may be beveled without materially affecting its strength and it must be remembered that a reduction of ⅛ inch in its width, will reduce the width of the valve ¼ inch, thereby decreasing the area on top. The over-travel must be considered, and a sufficient surface left when the valve is at extreme travel, to make a steam tight joint; ¼ inch is considered sufficient. The wear must also be considered, too narrow a bridge would not maintain a steam tight joint. The width of the bridge is usually less than the steam port, on American locomotives they vary from 15-16 to 1¼ inch.

EXHAUST PORT.

The exhaust port should be more than twice as wide as the steam port, especially with over travel unless inside clearance is used, as you will see by referring to Fig. 6; otherwise it would cramp or choke the exhaust. But it should not be made too wide, as it will add unnecessarily to the size of the valve, and hence to the pressure upon it, which adds to the friction, wear and tear, of all the valve gear; further than this the size of the exhaust port or cavity has no influence upon the valve. The rule for finding the width of the exhaust port is as follows: Add the width of one steam port to one half the travel of the valve, and from that amount subtract the width of one bridge, Another rule for determining the area of the exhaust port is to multiply the square of the diameter of the cylinder by .178.

OUTSIDE RIBS.

Except when Allen or special valves are used, the length of the valve seat is not particular; but if possible, they should be made wide enough to permit of a surface for the valve equal to the width of one bridge when the valve is at extreme travel

as shown in Fig. 6; unless that would permit of a shoulder being worn on the seat when engine is hooked up in working notch, which should be avoided.

THE VALVE.

If the valve has neither inside lap, nor inside clearance the exhaust arch should be the width of both bridges and exhaust port. If the valve has no outside lap there would be no cut off or expansion. If the valve had no inside lap, compression at one end and release at the other would be simultaneous. If the valve had no lap or lead the eccentric should be at right angle with the crank pin.

The more "outside lap" the valve has, the greater the throw required and the later the admission of steam takes place, it also hastens the cut off and prolongs expansion, and necessarily shortens the period the port is open. Outside lap has no effect on compression of exhaust.

"Inside lap" prolongs the period of expansion, hastens compression and thereby increases it. It retards and tends to choke the exhaust, but has no effect upon steam admission or point of cut off.

"Inside clearance" or negative inside lap, delays compression, but hastens the exhaust release, thereby making a quicker engine, but has no effect upon the cut off or point of admission. With inside clearance the point of compression and release as shown in Fig. 7 would be reversed, release taking place before compression. The evil effects of inside clearance in connecting the opposite ends of the cylinder can be overcome by adding an equal amount to the exhaust edge of the valve lip.

The least "travel" that will give a full port opening equals twice the outside lap of the valve, plus twice the steam port width. One half the travel of the valve should always be less than the width of the lap the steam port and the bridge added together. In order to keep the steam port wide open during any portion of the stroke the travel must be greater than the sum of the outside lap and the width of both steam ports, this is usually done on the locomotive. The more travel the valve has the longer the steam port will remain open therefore the freer the steam admission.

"Over travel" tends to choke the exhaust, increases the sharpness of the cut off, retards compression and gives a later release. In order to secure sufficient port openings with an early cut off it is necessary to give over travel at other points. When the cut off occurs too late by reason of over travel you can remedy the evil effects by increasing the out-

side lap. And delayed compression may be neutralized by increasing the inside lap, if the exhaust takes place too late cut out the inside lap, if there is none, give the valve inside clearance.

"Lead" increases as the cut off is made earlier, this is done by bringing the reverse lever nearer the center notch, and is caused by the radius of the link (as explained in Link Motion). Increased lead hastens every operation of the valve. The greater the speed the more lead is required to permit of smooth running. (See Rule 24 for Valve Setting).

"Clearance" is given to prevent the piston from striking either cylinder head in the event of lost motion in the main rod; it also helps to prevent bursting the cylinder when there is water in it. Clearance lessens the actual expansion rate owing to its waste space, but it also economizes on live steam, no engine can be constructed without some waste space between the valve and piston.

The "Angularity" of the connecting rod increases the lead in front and decreases it behind. It retards the cut-off and exhaust in front and hastens each behind. This evil is overcome by back-setting the saddle pin (see Link Motion, and Angularity of main rod).

MERITS OF THE SLIDE VALVE.

A slide valve, its seat and parts should be so proportioned that steam be admitted in sufficient volume at the beginning of the piston stroke, that the cut-off takes place at the earliest point at which the engine can develop required power, that release occurs at the latest point consistent with the speed required and before admission at the other end. That the exhaust closure be at that point at which compression shall be sufficient to arrest the motion of the reciprocating parts, and it may be nearly, or quite equal to the initial boiler pressure.

RELATIVE POSITIONS OF THE VALVE AND PISTON.

It is now time the reader should familiarize himself with the constantly changing positions of the valve and piston. But as we shall see later the motion of the piston is not symmetrical which is wholly due to the varying angularity of the main rod, so we shall first study the different positions of the crank pin during the various operations of the valve, and after we know the relative positions of the valve and crank pin we will study the relative positions of the crank pin and piston. In order to illustrate this subject clearly we have adopted four diagrams, most of the parts being represented by their center lines and

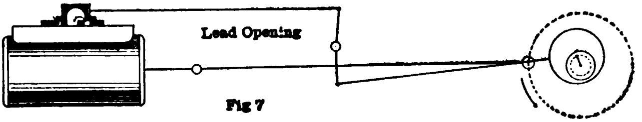


Fig 7

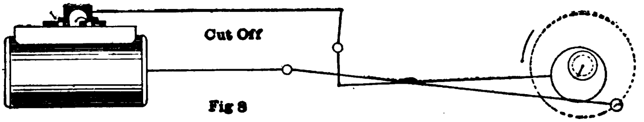


Fig 8

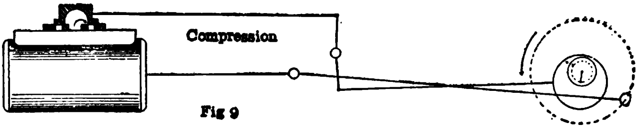


Fig 9

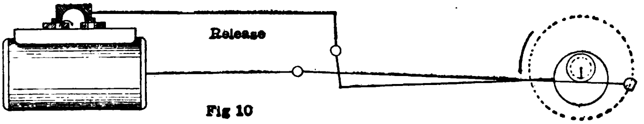


Fig 10

center points only, in order to make them as plain as possible the dimensions used for these illustrations are 18x24 inch cylinders; steam ports, 1¼ inches; exhaust port, 2¾ inches; bridges, 1⅛ inches; outside lap, 13-16 of an inch; inside lap, 1-16 of an inch; travel of valve, 5 inches. The diagrams representing full gear; the small arrows of these diagrams indicate the direction the pin is moving, and the larger dotted circle represents the path of the center of the crank pin, and the small dotted circle the path of the center of the eccentric.

Fig. 7 shows the valve at the point of lead opening, which was more clearly shown in Fig. 5. Now we find the crank pin is slightly above the forward dead center and almost at the beginning of a stroke, and the engine is beginning to take steam in the forward end of the cylinder.

Fig. 8 shows the valve at the point of cut-off as was shown by Fig. 2. We find the crank pin has traveled about three-fourths of its stroke and during that time the forward steam port remained open for the free admission of steam. At this point live steam is cut-off and the steam in the cylinder begins to expand.

Fig. 9 shows the point of compression, which was also shown by Fig. 3. At this point the exhaust edge of the valve closes the back steam port which you will notice has been open to the exhaust prior to the beginning of this stroke. The unexhausted steam that yet remains in the cylinder must now be compressed by the advancing piston until the piston has completed its stroke which will not be until the piston has reached the back dead center; but we find the crank pin is yet some distance below the back center, yet closer to it than it was at the point of cut-off.

Fig. 10 shows the valve at the point of release, as was shown in Fig. 4. At this point we find the exhaust edge of the valve releases the steam from the forward end of the cylinder where we have seen it was admitted during three fourths of this same stroke, until the valve had reached the point of cut-off where expansion began. Therefore we find that expansion lasts only from the point of cut-off to the point of release and as the crank pin has not yet reached the back dead center, we find that expansion lasts during the very small portion of the piston's stroke. Now you will notice that while the crank pin continues in the same rotary motion the motion of the valve has been reversed (it was reversed before the point of cut-off was reached); and it is now about ready to take steam at the back steam port, which it will do slightly before the crank pin reaches the back center as it did for this stroke before the pin reached the forward center. Then each operation of the valve will be repeated in the return stroke as they were in

this stroke. The reader who has carefully studied the different positions of the crank pin in the four preceding diagrams will readily understand the construction of Fig. 11, which combines all the positions of the crank pin shown in the preceding cuts and also the positions for the return stroke. The circle represents the path of the center of the crank pin.

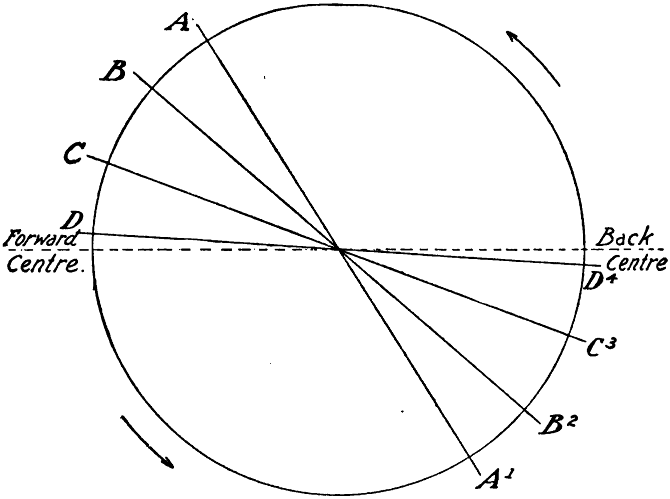


Fig. 11.

D indicates the point of admission as shown by Fig. 7.
A1 indicates the point of cut-off as shown by Fig. 8.
B2 indicates the "point" of compression as shown by Fig. 9.
C3 indicates the point of release as shown by Fig. 10.
D4 indicates the point of admission for the return stroke.
A indicates the point of cut-off for the return stroke.
B. indicates the point of compression for the return stroke.
C indicates the point of release for the return stroke.

Now while admission must always precede every other operation of the valve, you will notice by Fig. 11, that it is the last operation in each stroke and takes place slightly before the beginning of each stroke; this is caused by giving the engine lead and the distance the crank pin will be from each dead center at the point of lead opening will be in proportion to the

amount of lead given. If the valve has inside clearance instead of inside lap the points B2 and C3 and B and C would be reversed; while if the valve was line and line inside, release at one end and compression at the other would be simultaneous. As the reverse lever is drawn closer to the center notch each operation of the valve takes place earlier in the stroke.

RELATION BETWEEN MOTION OF CRANK-PIN AND MOTION OF PISTON.*

Now, since the aim of giving lap to a valve is to cause it to cut off steam at designated parts of the stroke of the piston, it will be necessary first to study the existing relation between the motion of the crank-pin and the motion of the piston.

In order to illustrate this subject plainly, we have adopted in Fig. 12 a shorter length for the connecting-rod, than is used in locomotives.

The circumference of the circle *A B M D*, drawn from the center of the axle, and with a radius equal to the distance between the center of axle and that of the crank-pin, represents the path of the latter. We will assume that the motion of the crank-pin is uniform, that is, that it will pass through equal spaces in equal times. The direction in which the crank-pin moves is indicated by the arrow marked 1, and the direction in which the piston moves is indicated by arrow 2.

In order to trace the motion of the piston it is not necessary to show the piston in our illustration, because the connection between the crosshead pin *P* and the piston is rigid; hence, if we know the motion of one of these we also know the motion of the other; they are alike

The line *A C* represents the line of motion of the center of crosshead pin *P*, consequently no matter what position the crank may occupy, the center *P* will always be found in the line *A C*. The semi-circumference *A B D* will be the path of the center of the crank-pin *P* during one stroke of the piston; the point *A* will be the position of the crank at the beginning of the stroke, and *B* the position of the same at the end of the stroke. The semi-circumference *A B D* is divided into 12 equal parts, although any other number would serve our purpose as well. The distance between the centers *D* and *P* represents the length of the connecting-rod.

From the point *A* as a center, and with a radius equal to *D P* (the length of the connecting-rod) an arc has been drawn, cutting the line *A C* in the point *a;* this point is the position of the center *P* of the crosshead pin, when the center of the crank is at *A*. Once

*** This construction of the slide-valve is from the pen of Mr. J. G. A. Meyer, M. E., whose authenticity on the subject is so well known that his name needs no introduction here.**

more, from the point 1 on the semi-circumference as a center and with the radius $D\ P$, another arc has been drawn cutting the line $A\ C$ in the point $1p$, and this point indicates the position of the cross-head pin when the crank-pin is at the point 1. In a similar manner the points $2p$, $3p$, $4p$, etc., have been obtained, and these points indicate the various positions of cross-head pin when the crank-pin is in the corresponding positions as 2, 3, 4, etc.

Now notice the fact that the spaces from A to 1 and from 1 to 2, etc., in the semi-circumference $A\ B\ D$ are all equal, and the crank-pin moves through each of these spaces in equal times, that is, if it requires one second to move from A to 1, it will also require one second to move from 1 to 2. The corresponding spaces from a to $1p$ and from $1p$ to $2p$, etc., on the line $A\ C$ are not equal, and yet, the crosshead pin must move through these spaces in equal times; if it requires one second to move from a to $1p$, it will also require one second to move from $1p$ to $2p$. But this last space is greater than the first. Here, then, we see that the crosshead pin, and therefore the piston, has a variable motion, that is, the piston will, at the commencement of its stroke, move comparatively slow, and increase in speed as it approaches the center of the stroke, and when the piston is moving away from the center of stroke, its speed is constantly decreasing. This variable motion of the piston is mostly caused by changing its rectilinear motion into a uniform rotary motion, and partly by the angle formed by the center line $D\ P$ of the connecting-rod and the line $A\ C$, an angle which is constantly changing during the stroke. Also notice that the distance from a to $1p$ nearest one end of the stroke is smaller than the distance from b to $11p$ nearest the other end of the stroke, and if we compare the next space $1p$ to $2p$ with the space $11p$ to $10p$, we again find that the former is smaller than the latter, and by further comparison we find that all the spaces from a to $6p$ are smaller than the corresponding spaces from b to $6p$, and consequently when the crank-pin is at point 6, which is the center of the path of the crank-pin during one stroke, the crosshead pin P will be at $6p$ and not in the center of its stroke. Thus we see that the motion of the piston is not symmetrical, and this is wholly due to the varying angularity of the connecting-rod during the stroke. If we make the connecting-rod longer, but leave the stroke the same, the difference between the spaces b to $11p$ and a to $1p$ will be less, and the same can be said of the other spaces. Again, if we consider the length of the connecting-rod to be infinite, then the difference between the spaces nearest the ends of the stroke will vanish, and the same result is true for the other spaces. Hence, when the length of the connecting-rod is assumed to be infinite the motion of the piston will be symmetrical, but still remain variable, in fact the piston will have the same motion as that shown in Fig. 13. In this figure we have dispensed with the connecting-rod, and in its place extended the piston-rod, and to its end a slotted crosshead is attached in which the crank-pin is to work. Al-

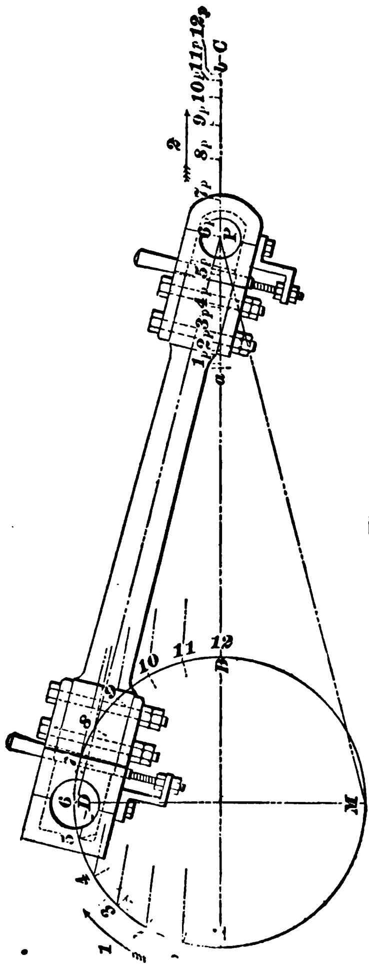


Fig. 12.

though such mechanism is never used in a locomotive, yet with its aid we can establish a simple method for finding the position of the piston when that of the crank is known. In this figure, as in Fig. 12, the circumference *A B D M* will represent the path of the center of the crank-pin, and from the nature of this mechanism it must be evident that at whatever point in the circumference *A B D M* the crank-pin center may be located, the center line *i h*, of the slotted crosshead will always stand perpendicular to the line *A C*, and also pass through the center of crank-pin.

In Fig. 13, when the crank-pin is at *A*, the piston will be at the commencement of its stroke. During the time the crank-pin travels from *A* to point 8 the piston will travel through a portion of its stroke equal to the length *A E*, which is the distance between the dotted line *i h* and the full line *i h*. If now we assume the points 1, 2, 3, etc., in the semi-circumference *A B D* to be the various positions of the crank-pin during one stroke, and then drawn through these points lines perpendicular to the line *A C*, cutting the latter in the points 1*p*, 2*p*, 3*p*, we obtain corresponding points for the position of the piston in the cylinder. Thus, for instance, when the crank-pin is at point 1 the piston will then have moved from the commencement of its stroke through a distance equal to *A* 1*p*, and when the crank-pin is at point 2, the piston will then have traveled from *A* to 2*p*, and so on.

From the foregoing, we can establish a simple method, as shown in Fig. 14, for finding the position of the piston when that of the crank is known. The diameter, *A B*, represents the stroke of the piston, and the semi-circumference *A B D* represents the path of the center of the crank-pin during one stroke. For convenience, we may divide the diameter into an equal number of parts, each division indicating one inch of the stroke. In this particular case (Fig. 14), we have assumed the stroke to be 24 inches ; hence the diameter has been divided into 24 equal parts. Let the arrow indicate the direction in which the crank is to turn, and *A* the beginning of the stroke; then, to find the distance through which the piston must travel from the commencement of its stroke during the time that the crank travels from *A* to *b*, we simply draw through the point *b* a straight line *b c* perpendicular to *A B*; the distance between the line *b c* and the point *A* will be that portion of the stroke through which the piston has traveled, when crank-pin has reached the point *b*. In our figure we notice that the line *b c* intersects *A B* in the point 6; hence the piston has traveled six inches from the commencement of the stroke.

If this method of finding the position of the piston, when that of the crank is known, is thoroughly understood, then the solutions of the following problems relating to lap of the slide-valve will be comparatively easy:

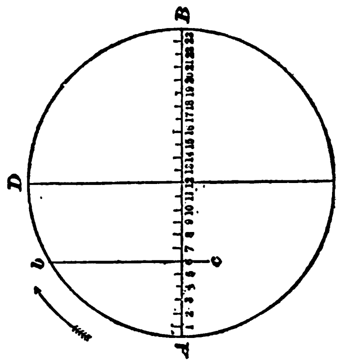


Fig. 14.

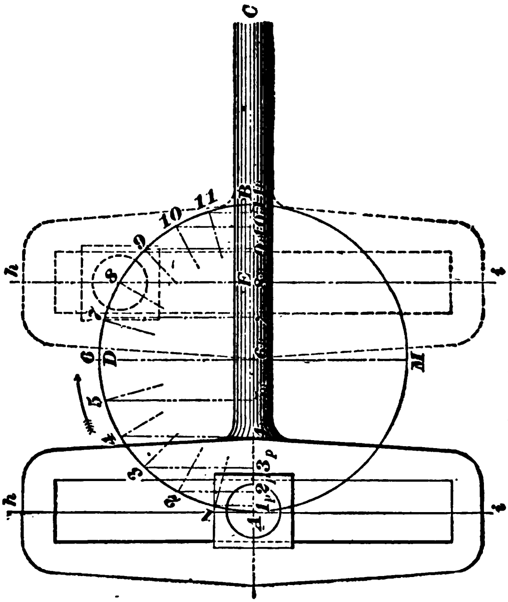


Fig. 13.

PROBLEMS RELATING TO LAP OF THE SLIDE-VALVE.

To find the point of cut-off when the lap and travel of the valve are given, the valve to have no lead.

Example 18.—Lap of valve is one inch; travel, 5 inches; no lead; stroke of piston, 24 inches. At what part of the stroke will the steam be cut off?

We must first find the center *c*, Fig. 15, of the circle *a b m*, whose circumference represents the path of the center of eccentric, and this is found, as the reader will remember, by placing the valve in a central position, as shown in dotted lines in this figure. Then the edge *c* of the valve will be the center of the circle. The valve drawn in full lines shows its position at the commencement of the

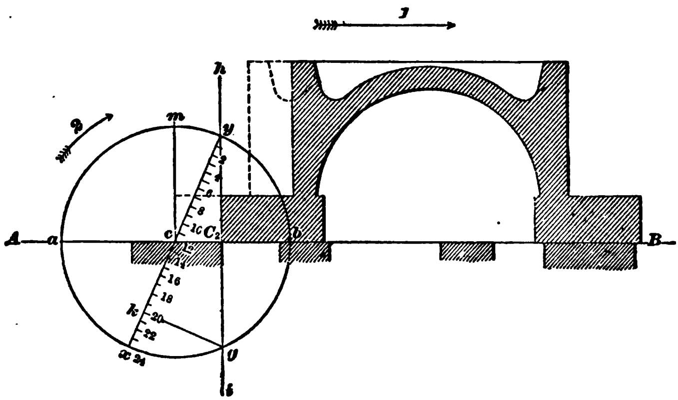


Fig. 15.

stroke of piston. Through the edge c_2 draw the line *i h* perpendicular to the line *A B*; the line *i h* will intersect the circumference *a b m* in the point *y*, and this point will be the center of eccentric when the piston is at the beginning of its stroke. Now, assume that the circumference *a b m* also represents, on a small scale, the path of the center of the crank-pin; then the diameter *y x* of this circle will represent the length of the stroke of the piston; the position of this diameter is found by drawing a straight line through the point *y* (the center of the eccentric when the piston is at one end of its stroke) and the center *c*. Also assume that the point *y* represents the center of the crank-pin when the piston is at the beginning of its stroke. To make the construction as plain as possible, divide the diameter *y x* into 24 equal parts, each representing one inch of

the stroke of piston, and for convenience number the divisions as shown. The arrow marked 1, shows the direction in which the valve must travel, and arrow 2 indicates the direction in which the center y must travel. Now it must be evident, because the points y_1 and C_2 will always be in the same line, that during the time the center y of the eccentric travels through the arc $y\ g$, the valve not only opens the steam port, but, as the circumference $a\ b\ m$ indicates, travels a little beyond the port, and then closes the same, or, in short, during the time the center of eccentric travels from y to g, the port has been fully opened and closed; and the moment that the center of eccentric reaches the point g, the admission of steam into the cylinder is stopped. We have assumed that the point y also represents the position of the center of crank-pin at the beginning of the stroke; and, since the crank and eccentric are fastened to the same shaft, it follows that during the time the center of eccentric travels from y to g the crank-pin will move through the same arc, and when the steam is cut off the crank-pin will be at the point g. Therefore, through the point g draw a straight line $g\ k$ perpendicular to the line $y\ x$; the line $g\ k$ will intersect the line $y\ x$ in the point k, and this point coincides with the mark 20; hence steam will be cut off when the piston has traveled 20 inches from the beginning of its stroke.

LEAD WILL AFFECT THE POINT OF CUT-OFF.

In Fig. 15 the valve had no lead; if, now, in that figure, we change the angular advance of the eccentric so that the valve will have lead, as shown in Fig. 16, then the point of cut-off will also be changed. How to find the point of cut-off when the valve has lead, is shown in Fig. 16.

Example 19.—The lap of valve is 1 inch, its travel 5 inches; lead ¼ of an inch (this large amount of lead has been chosen for the sake of clearness in the figure); stroke of piston, 24 inches; at what part of the stroke will the steam be cut off?

On the line $A\ B$, Fig. 16, lay off the exhaust and steam ports; also on this line find the center c of the circle $a\ b\ m$ in a manner similar to that followed in the last construction, namely, by placing the valve in a central position, as shown by the dotted lines, and marked D, and then adopting the edge c of the valve as the center of the circle $a\ b\ m$; or, to use fewer words, we may say from the outside of the edge s of the steam port, lay off on the line $A\ B$ a point c whose distance from the edge s will be equal to the lap, that is, 1 inch. From c as a center, and with a radius of 2½ inches (equal ½ of the travel), describe the circle $a\ b\ m$, whose circumference will represent the path of the center of eccentric. The lead of the valve in a locomotive is generally $\frac{1}{32}$ and sometimes as much as $\frac{1}{16}$ of an inch, when the valve is in full gear, but for the sake of distinctness we have adopted in this construction a lead of ¼ of an inch. Draw the section of the valve, as shown in full lines, in a position that it will occupy

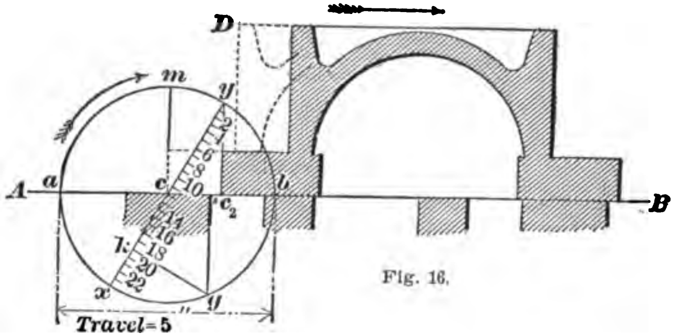

D
m
y
a
A
c
b
B
c_2
k
x
g
2
4
6
8
10
14
16
18
20
22
Travel=5"

Fig. 16.

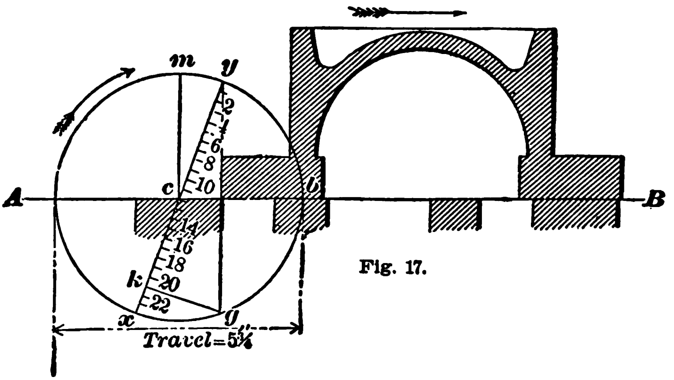

m
y
A
c
b
B
k
x
g
2
4
6
8
10
14
16
18
20
22
Travel=5¼"

Fig. 17.

when the piston is at the beginning of its stroke, and consequently the distance between the edge c_2 of the valve and the edge s of the steam port will, in this case, be $\frac{1}{4}$ of an inch. Through c_2 draw a straight line perpendicular to $A\,B$, intersecting the circumference $a\,b\,m$ in the point y; this point will be the center of the eccentric when the piston is at the beginning of its stroke, and since it is assumed that the circumference $a\,b\,m$ also represents the path of the center of the crank-pin, the point y will also be the position of the same when the piston is at the commencement of its stroke. Through the points y and c draw a straight line $y\,x$, to represent the stroke of the piston, and divide it into 24 equal parts. Through the point s draw a straight line perpendicular to $A\,B$, intersecting the circumference $a\,b\,m$ in the point g, and through g draw a straight line perpendicular to $y\,x$, and intersecting the latter in the point k; this point will be the point of cut-off, and since the distance between the point k and 19 is about $\frac{1}{8}$ of the space from 19 to 20, we conclude that the piston has traveled $19\frac{1}{8}$ inches from the beginning of its stroke when the admission of steam into the cylinder is suppressed.

Here we see that when a valve has no lead, as in Fig. 15, the admission of steam into the cylinder will cease when the piston has traveled 20 inches; and when the angular advance of the eccentric is changed, as in Fig. 16, so that the valve has $\frac{1}{4}$ of an inch lead, the point of cut-off will be at $19\frac{1}{8}$ inches from the beginning of the stroke, a difference of $\frac{7}{8}$ of an inch between the point of cut-off in Fig. 15 and that in Fig. 16. But the lead in locomotive valves in full gear is only about $\frac{1}{32}$ of an inch, which will affect the point of cut-off so very little that we need not notice its effect upon the period of admission, and, therefore, lead will not be taken into consideration in the following examples.

THE TRAVEL OF THE VALVE WILL AFFECT THE POINT OF CUT-OFF.

Fig. 17 represents the same valve and ports as shown in Fig. 15, but the travel of the valve in Fig. 17 has been increased to $5\frac{3}{4}$ inches. The point of cut-off k has been obtained by the same method as that employed in Figs. 15 and 16, and we find that this point k coincides with point 21. Now, notice the change caused by an increase of travel; when the travel of the valve is 5 inches, as shown in Fig. 15, the admission of steam into the cylinder will cease when the piston has traveled 20 inches from the commencement of its stroke, and when the travel of the same valve is increased $\frac{3}{4}$ of an inch, as shown in Fig. 17, the admission of the steam will not be suppressed until the piston has traveled 21 inches. Here we notice a difference of 1 inch between the two points of cut-off. But it must be remembered that when the travel of a valve for a new engine is to be found or established, the point of cut-off does not enter the question; we simply

assign such a travel to the valve that steam ports will be fully opened, or slightly more, when the valve is in full gear. The point of cut-off is regulated by the lap and position of the eccentric.

In order to find the point of cut-off it is not necessary to make a drawing of the valve, as has been done in Fig. 15. The only reason for doing so was to present the method of finding the point of cut-off to the beginner in as plain a manner as possible. In order to show how such problems can be solved without the section of the valve, and, consequently, with less labor, another example, similar to Example 18, is introduced.

Example 20.—Lap of valve is 1⅜ inches; travel, 5¼ inches; stroke of piston, 24 inches; width of steam port, 1¼ inch; find the point of cut-off.

Fig. 18. Draw any straight line, as *A B;* anywhere on this line mark off 1¼ inch, equal to the width of the steam port. From the edge *s* of the steam port lay off on the line *A B* a point *c*, the distance between the points *s* and *c* being 1⅜ inches; that is, equal to the amount of lap. From *c* as a center, and with a radius equal to half the travel, namely, 2⅝ inches, draw a circle, *a b m;* the circumference of this circle will represent the path of the center of the eccentric, and also that of the crank-pin. Through *s* draw a straight line *i h* perpendicular to *A B;* this line *i h* will intersect the circumference *a b m* in the points *y* and *g*. Through the points *y* and *c* draw a straight line *y x;* the diameter *y x* will represent the stroke of the piston. Divide *y x* into 24 equal parts; through the point *g* draw a straight line *g k* perpendicular to *y x*, and intersecting *y x* in the point *k*, and this point is the point of cut-off. Since *k* coincides with the point 18, it follows that the piston had traveled 18 inches from the beginning of its stroke when the flow of the steam into the cylinder ceased.

Now we may reverse the order of this construction and thus find the amount of lap required to cut off steam at a given portion of the stroke.

Example 21.—Travel of valve is 5¾ inches; stroke of piston, 30 inches; steam to be cut off when the piston has traveled 22 inches from the beginning of the stroke; width of steam port, 1⅜ inch; find the lap.

Fig. 19. Draw a circle *a b m* whose diameter is equal to the travel of the valve, viz., 5¾ inches. Through the center *c* draw the diameter *y x*. In this figure we have drawn the line *y x* vertically, which was done for the sake of convenience; any other position for this line will answer the purpose equally well. The circumference *a b m* represents the path of the center of the eccentric, also that of the crank-pin; the diameter *y x* will represent the stroke of the piston, and, therefore, is divided into 30 equal parts. The steam is to be cut off when the piston has traveled 22 inches from the beginning of the stroke, therefore, through the point 22 draw a straight line *g k* perpendicular to *y x*, the line *g k* intersecting the circumference *a b m* in the point *g*. Join the points *y* and *g* by a straight line. Find the

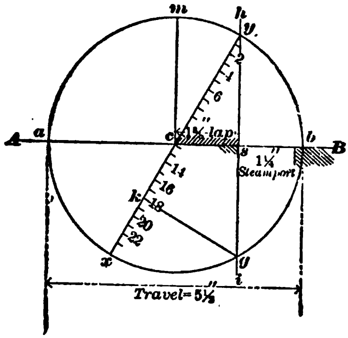

m
h
y
2
4
6
A
a
c
lap
b
B
s
1¼"
Steam port
14
16
k
18
20
22
x
g
i
Travel=5⅓"

Fig. 18.

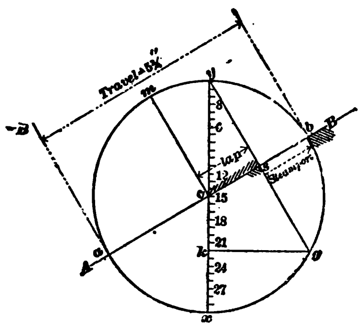

Travel
m
y
8
6
lap
12
15
18
21
24
27
b
B
s
Steam port
c
a
A
k
g
x

Fig. 19.

center s of the line $y\ g$, and through s and perpendicular to the line $y\ g$, draw the line $A\ B$; if the latter line is drawn accurately it will always pass through the center c. The distance between the points s and c will be the amount of lap required, and in this example it is $1\frac{7}{16}$ inch.

It sometimes occurs, in designing a new locomotive, and often in designing stationary or marine engines, that only the width of steam

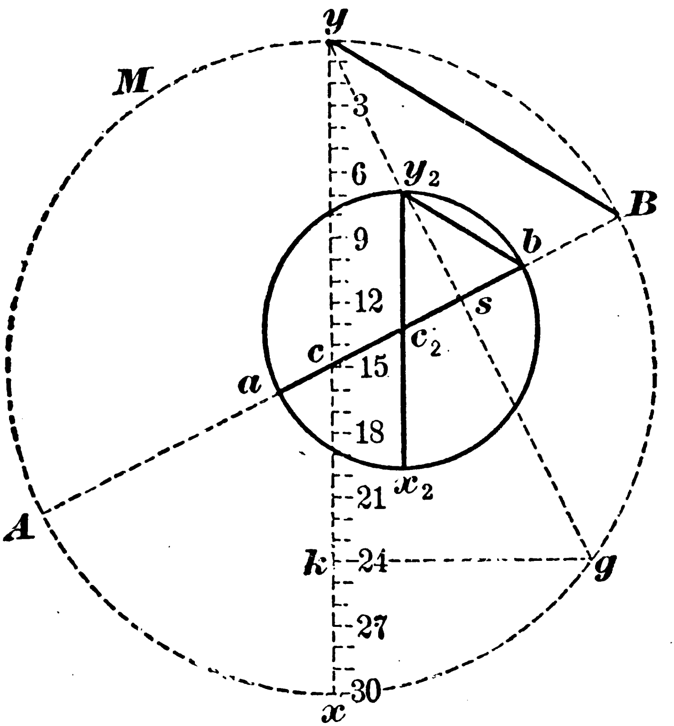


Fig. 20.

port and point of cut-off is known, and the lap and travel of the valve is not known. In such cases both of these can be at once determined by the following method:

Example 22.—The width of the steam port is 2 inches; the stroke

of piston, 30 inches; steam to be cut off when the piston has traveled 24 inches from the beginning of its stroke; find the lap and travel of the valve.

Fig. 20. Draw any circle, as *A B M*, whose diameter is larger than what the travel of the valve is expected to be. Through the center *c* draw the diameter *y x*, and, since the stroke of piston is 30 inches divide *y x* into 30 equal parts. Steam is to be cut off when the piston has traveled 24 inches; therefore, through point 24 draw a straight line *g k* perpendicular to the diameter *y x*, intersecting the circumference *A B M* in the point *g*. Join the points *y* and *g* by a straight line; through the center *s* of the line *y g* draw a line *A B* perpendicular to *y g*. So far, this construction is precisely similar to that shown in Fig. 19, and in order to distinguish this part of the construction from that which is to follow, we have used dotted lines; for the rest full lines will be used. It will also be noticed by comparing Fig. 20 with Fig. 19 that, if the diameter *A B* had been the correct travel of valve, then *c s* would have been the correct amount of lap. But we commenced this construction with a travel that we know to be too long; hence, to find the correct travel and lap, we must proceed as follows: Join the points *B* and *y*. From *s*, toward *B*, lay off on the line *A B* a point *b*; the distance between the points *s* and *b* must be equal to the width of the steam port plus the amount that the valve is to travel beyond the steam port, which, in this example, is assumed to be ⅛ of an inch. Therefore the distance from *s* to *b* must be 2⅛ inches. Through *b* draw a straight line $b\ y_2$ parallel to *B y*, intersecting the line *y g* in the point y_2. Through the point y_2 draw a straight line $y_2\ x_2$ parallel to the line *y x*, and intersecting the line *A B* in the point c_2. From c_2 as a center, and with a radius equal to $c_2\ b$, or $c_2\ y_2$, describe a circle $a\ b\ y_2$. Then *a b* will be the travel of the valve, which, in this case, is 7⅝ inches, and the distance from c_2 to *s* will be the lap, which, in this example, is 1 11/16 inch.

PRACTICAL CONSTRUCTION OF THE SLIDE-VALVE.

It should be obvious, and, therefore, almost needless to remark here, that the foregoing graphical methods employed in the solutions of the problems relating to the slide-valve are applicable to everyday practice, the writer believes that these methods are the simplest and best to adopt for ordinary use, and without these it would be difficult to construct a valve capable of performing the duty assigned to it. Of course, when a graphical method is employed, great accuracy in drawing the lines is necessary,

We will give a practical example, in which one of the objects aimed at, is to show the application of one of the foregoing methods to ordinary practice.

Example 2.. –The width of the steam ports is 1¼ inch; length of the same 14 inches; thickness of bridges 1⅛ inch; width of exhaust port 2½ inches; travel of valve 4¾ inches; stroke 24 inches; steam to

be cut off when the piston has traveled $20\frac{3}{4}$ inches from the beginning of its stroke; the edges of the exhaust cavity are to cover the steam ports, and not more, when the valve stands in a central position; construct the valve.

Fig. 21. Draw a straight line *A B* to represent the valve-seat through any point in *A B;* draw another line *D C* perpendicular to *A B;* the line *D C* is to represent the center of exhaust port and the center of valve. Draw the exhaust port, bridges and steam ports as shown.

The question now arises: How long shall we make the valve? Or, in other words, what shall be the distance between the outside edges of the valve c and c_2? If the valve had to admit steam during the whole stroke of the piston, or as the practical man would say, "follow full stroke," then the distance between the edges c and c_2 would be equal to the sum of twice the width of one steam port plus twice the width of one bridge plus the width of the exhaust port,

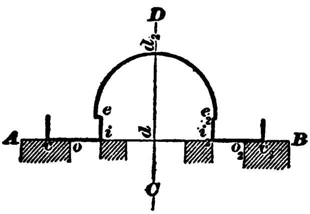


Fig. 21.

hence we would have $2\frac{1}{2}+2\frac{1}{4}+2\frac{1}{2}=7\frac{1}{4}$ inches for the length of the valve. But, according to the conditions given in the example, the valve must cut off steam when the piston has traveled $20\frac{3}{4}$ inches, therefore the valve must have lap, and the amount of lap that is necessary for this purpose must be determined by the method shown in Fig. 19, and given in connection with Example 21. Following this method, we find that the required lap is $\frac{7}{8}$ of an inch, therefore the total length of the valve will be $7\frac{1}{4}+(\frac{7}{8}\times 2)=9$ inches; or, we may say, that the distance between the edges c and c_2 must be equal to twice the width of one steam port plus twice the width of one bridge plus the width of the exhaust port plus twice the lap, consequently we have $2\frac{1}{2}+2\frac{1}{4}+2\frac{1}{2}+1\frac{3}{4}=9$ inches for the length of the valve. Through the points c and c_2 (each point being placed $4\frac{1}{2}$ inches from the center line *C D*), draw lines perpendicular to *A B;* these lines will represent the outside surfaces containing the edges c and c_2. These surfaces must be square with the surface *A B*, because, if they are not so, but are such as shown in Fig. 24, the distance between the edges c and c_2 will decrease as the valve wears, and when this occurs, the valve will not cut off the steam at the proper time. Now,

in regard to the cavity of the valve. One of the conditions given in our example is, that the edges of the cavity must cover the steam ports, and no more, when the valve stands in a central position, therefore the inner edges i and i_2 of the valve must be 4¾ inches apart, which is equal to twice the width of one bridge plus the width of the exhaust port; consequently, when the valve stands midway of its travel, the inner edges of the valve (being 4¾ inches apart), the inner edges of the steam ports coincide. Through the points i and i_2 (each being placed 2⅜ inches from the center line $C\,D$), draw the straight lines $i\ e$ and $i_2\ e_2$ perpendicular to $A\ B$. These lines will represent the sides of the cavity containing the inner edges i and i_2 of the valve, and these sides must be square with the surface $A\ B$; if these are otherwise, for instance, such as shown in Fig. 24, the distance between the edges i and i_2 will change as the valve wears, and then the valve will not perform its duty correctly. The

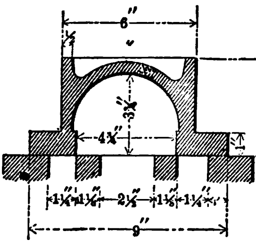


Fig. 22.

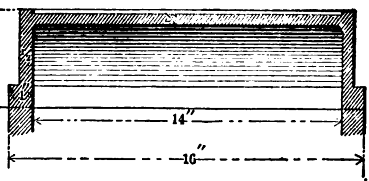


Fig. 23.

depth $d\ d_2$ of the cavity is generally made from 1¼ to 1½ times the width of the exhaust port. The writer believes that making the depth of the cavity 1½ times the width of the exhaust port is the best practice. In our example the width of the exhaust port is 2½ inches, and 2½+1¼=3¾ inches, which will be the distance from d to d_2, that is, the depth of the cavity. The curved surface of the cavity is gen-

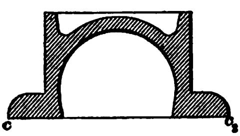


Fig. 24.

erally a cylindrical surface, and when it is so, as in our example, this surface must be represented in Fig. 21 by an arc of a circle. The sides $i\ e$ and $i_2\ e_2$ must be planed, and to do this conveniently, these sides must extend a little beyond the curved surface, toward the center $C\,D$. Consequently, through the point d_2 draw an arc whose center

is in the line $C D$, and whose radius is such that will allow the sides to project about $\frac{1}{16}$ of an inch. Here, then, we have lines which completely represent the cavity of the valve and the valve face. If we now add to these lines the proper thickness of metal as shown in Fig. 22, this section of the valve will be complete.

Fig. 23 shows a section of the valve taken at right angles to that shown in Fig. 22. Since the ports are 14 inches long, the cavity of the valve must be 14 inches wide, as shown. The amount that the valve overlaps the ends of the steam ports must be sufficient to prevent leakage. For a valve of the size here shown, 1 inch overlap is allowed, and the thickness of metal around the cavity is generally one-half of an inch. For smaller valves the overlap at each end of the steam port is from $\frac{3}{4}$ to $\frac{7}{8}$ of an inch, and the thickness of metal around the cavity is $\frac{3}{8}$ of an inch.

The valve here shown is suitable for a locomotive cylinder 16 inches in diameter, and a piston speed of 525 feet per minute, and the dimensions here given agree with those of the valves that are at present in use.

INSIDE LAP, CLEARANCE, AND INSIDE LEAD.

Now, a few words in regard to some other terms used in connection with the slide-valve.

Inside Lap.—The amount that the inside edges i and i_2 of the valve, Fig. 25, overlap the inside edges s and s_2 of the steam ports, when the valve stands midway of its travel, is called inside lap; thus, the distance from s to i, or from s_2 to i_2, represents the inside lap. Its purpose is to delay the release of steam.

The amount of inside lap is comparatively small, rarely exceeding $\frac{1}{8}$ of an inch, and in a number of locomotives the valves have no inside lap. Rules for determining the inside lap cannot be given, because engineers do not agree on this subject. The writer believes that for slow-running locomotives, particularly if these have to run over steep grades, a little inside lap will be beneficial. For ordinary passenger locomotives, running on comparatively level roads, no inside lap should be used,

Inside Clearance.—When the valve stands midway of its travel, as shown in Fig. 26, and its inside edges i and i_2 do not cover the steam ports, then the amount by which each edge of the valve comes short of the inner edges of the steam ports is called inside clearance; thus, the distance from i to s, or from i_2 to s_2, represents inside clearance. The purpose of inside clearance is to hasten the release, and is sometimes adopted in very fast-running locomotives. It seldom exceeds $\frac{1}{64}$ of an inch. Good judgment and great experience are required for determining the amount of clearance, and for deciding for what classes of locomotives it should be used. In ordinary passenger locomotives the valves have no inside clearance.

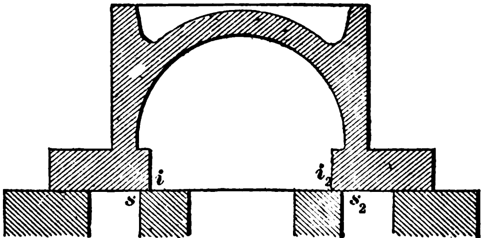


Fig. 25.

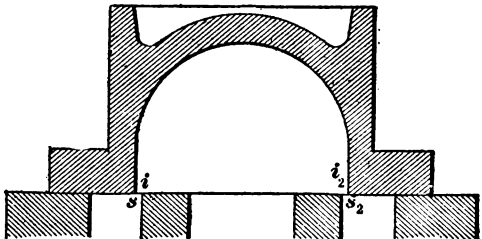


Fig. 26.

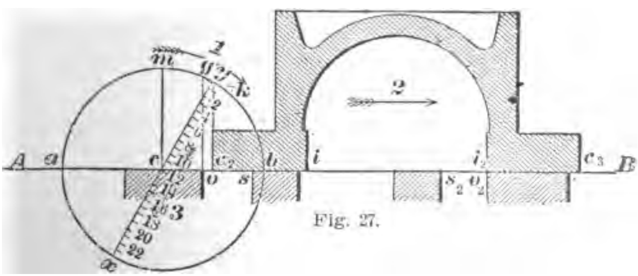


Fig. 27.

The width of opening of the steam port for the release of steam at the beginning of the stroke is called inside lead; thus, when the piston is at the beginning of its stroke, and the valve occupying the position as shown in Fig. 27, then the distance between the inner edges i_2 of the valve and the inner edge s_2 of the steam port is called inside lead. The simple terms "lead" and "lap" are used among engineers to designate outside lead and lap; hence, the necessity of using the terms "inside lead" and "inside lap" when such is meant.

THE EVENTS OF THE DISTRIBUTION OF STEAM.

In the distribution of steam during one revolution of the crank, four distinct events occur, namely·

1st. The admission of steam.

2d. The cutting off, or, in other words, the suppression of steam.

3d. The release of steam.

4th. The compression of steam.

The outside edges c_2 and c_3 of the valve, and the outside edges o and o_2 of the steam ports, will regulate the admission and suppression of steam; the inner edges i and i_2 of the valve and the inner edges s and s_2 of the steam ports control the release and compression of steam. The parts of the stroke of the piston during which these events will happen can be found by the following methods:

Example 24.—Travel of valve, 5 inches; lap, 1 inch; lead, ¼ of an inch; stroke of piston, 24 inches; no inside lap or clearance. Find at what part of the stroke the admission, suppression, release and compression will take place.

In Figs. 27, 28 and 29 the valve occupies different positions, but the sections of the valve in these figures are exactly alike, because they represent one and the same valve. In Fig. 27 the distance between the edge c_2 of the valve and the edge o of the steam port is ¼ of an inch, which is the amount of lead given in our example; hence, this position of the valve indicates that the piston is at the beginning of its stroke. In Fig. 28 the edge c_2 of the valve and the edge o of the steam port coincide, and, since the valve is moving in the direction indicated by arrow 2, the suppression commences, or, in other words, the valve is cutting off steam when it is in the position as here shown. In Fig. 29 the inside edge i of the valve coincides with the inner edge s of the steam port, and, since the valve is moving in the direction indicated by arrow 2, the release must commence when the valve arrives in the position here shown.

In Figs. 27, 28 and 29 the distances from the outside edge o of the steam port to the center c of the circle $a\ b\ m$ are equal; that is, the points c and o are one inch apart, which is the amount of lap. The diameters of the circles $a\ b\ m$ are all five inches long, which is the travel of the valve given in the example, and the circumference of each circle represents the path of the eccentric, and also the path of the center of the crank-pin. The point y in these figures represents

the position of the center of eccentric when the piston is at the beginning of its stroke. The distance between the point y and m is the same in all figures, and consequently the angles formed by the lines $y\ x$ and $A\ B$ are equal.

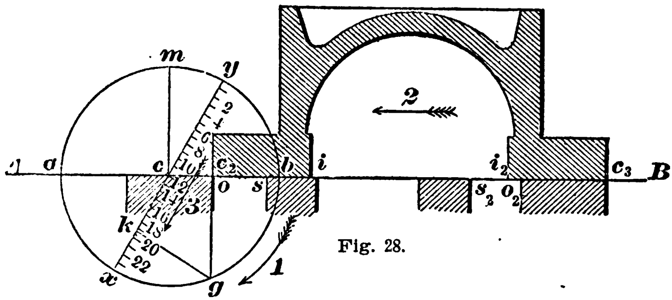


Fig. 28.

When the valve occupies the position as represented in Fig. 27, the center of crank-pin will be in the line $A\ B$, and since the piston will then be at the beginning of its stroke, it follows that the line $A\ B$ will indicate the direction in which the piston must move. In order to compare the relative position of the piston with that of the valve with as little labor as possible we shall assume that the direc-

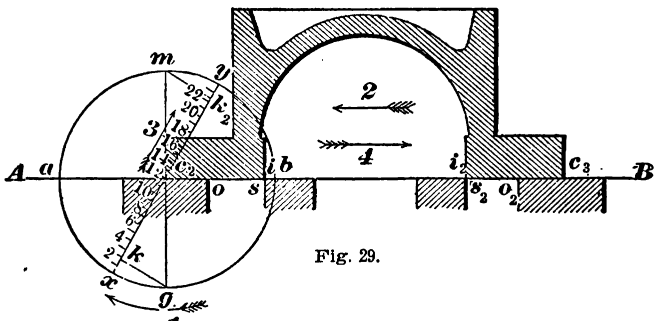


Fig. 29.

tion in which the piston moves is represented by the line $y\ x$, instead of the line $A\ B$; hence the point y will not only show the position of the center of the eccentric, but it will also indicate the position of the center of the crank-pin when the piston is at the commencement of its stroke. If these remarks are thoroughly understood, there will be no difficulty in comprehending that which is to follow.

Now let us trace the motions of the valve and piston and thus determine at what part of the stroke the events (previously named) will take place. When the piston is moving in the direction as indicated by the arrow marked 1, Fig. 27, the center of eccentric will move through part of the circumference *a b m*, and the valve will travel in the direction indicated by the arrow 2, and thus opening the steam port wider and wider until the end *b* of the travel is reached; then the valve will commence to return, and as it moves toward the center *c*, the steam port gradually closes, until the valve reaches the position as shown in Fig. 28, then the steam port will be closed and steam cut off. To find the position of the piston when the valve is cutting off steam, we draw through the edge c_2 of the valve, Fig. 28, a straight line $c_2\,g$, perpendicular to *A B*, and intersecting the circumference *a b m* in the point *g;* through this point draw a line perpendicular to *y x* intersecting the latter in the point *k*, and this point *k* being 19⅛ inches from *y* indicates that the piston has traveled 19⅛ inches from the beginning of its stroke before the steam is cut off, and that steam has been admitted into the cylinder during the time the piston traveled from *y* to *k*. As the piston continues to move toward the end *x* of the stroke the valve will move in the direction of the arrow 2, Fig. 28, and the steam port will remain closed so that no steam can enter the cylinder or escape from it, hence the steam that is now confined in the cylinder must push the piston ahead by its expansive force, but the moment that the valve reaches the position as shown in Fig. 29 the release of steam will commence. To find the corresponding position of piston we draw through the edge c_2 of the valve Fig. 29 a line $c_2\,g$, perpendicular to *A B* intersecting the circumference *a b m* in the point *g*. Through this point draw a line *g k*, perpendicular to *y x*, intersecting the latter in the point *k*, and this point *k* being 22⅜ inches from the beginning of the stroke indicates that the piston has traveled through this distance when the release of steam commences. Now notice, the steam is cut off when the piston has traveled 19⅛ inches, and the release of steam commences when the piston has traveled 22⅜ inches, consequently the steam is worked expansively during the time the piston moves 3¼ inches of its stroke. The steam port will remain open to the action of the exhaust during the time the piston completes its stroke and moves through a portion of its return stroke. In the meantime the valve will move to the end *a* of the travel and return, as in dicated by arrow 4, and the moment that the valve again reaches the position shown in Fig. 29, the release of steam will be stopped. To find the corresponding position of the piston, draw through the edge c_2 of the valve Fig. 29 a straight line $c_2\,m$ perpendicular to *A B* intersecting the circumference *a b m* in point *m*. Through this point draw a straight line $m\,k_2$ perpendicular to *y x*, and intersecting the latter in the points k_2. Since the distance between the points *x* and k_2 is 22¼ inches, it follows, that the piston has moved through 22¼ inches of its return stroke, by the time that the release of steam will

cease. As the valve continues its travel in the direction of arrow 4, Fig. 29, the steam port will remain closed until the edge c_2 of the valve coincides with the outer edge o of the steam port, and during this time, the steam which remained in the cylinder, is compressed, but as soon as the edge c_2 of the valve passes beyond the steam port edge o, the admission of steam into the cylinder will commence. To find the corresponding position of the piston, draw through the outer edge o of the steam port, Fig. 27, a straight line $o\ g$, perpendicular to $A\ B$ and intersecting the circumference $a\ b\ m$ in the point g; through this point draw a line $g\ k$ perpendicular to $y\ x$ intersecting the latter in the point k, and since the distance between the points x and k is 23⅞ inches, we conclude that the piston has moved 23⅞ inches of its return stroke before the admission of steam will begin. Here we see that steam will be admitted into the cylinder before the return stroke of the piston is completed, and that is the object of lead, as has been stated before. Notice once more the compression of steam will commence when the piston has traveled 22¼ inches of its return stroke, and will cease when the piston has traveled 23⅞ inches of its return stroke, hence the steam is compressed during the time that the piston travels through 1⅝ inches.

In each one of these figures the point g represents the relative position of the center of eccentric to that of the valve shown in the figure. The point g will always be found in the circumference $a\ b\ m$, and in a straight line $c_2\ g$, drawn perpendicular to $A\ B$, and the former passing through the outer edge c_2 of the valve.

The reason why the point g should in all cases be found in the straight line $c_2\ g$ drawn through the outside edge c_2 of the valve, is this, when the center c of the circle $a\ b\ m$ is placed on the line $A\ B$ in such a position (and as has been done in these figures), so that the distance between the center c and the outside edge o of the steam port is equal to the lap, then the center g of the eccentric and the outer edge c_2 of the valve will always lie in the same straight line drawn perpendicular to $A\ B$. If the distance between center c and the outer edge o of the steam port is greater or less than the lap, then the center of the eccentric and outside edge of the valve will not lie in the same straight line drawn perpendicular to the line $A\ B$. Here, then, we can conceive the necessity of placing the center c of the circle $a\ b\ m$ in the position as shown in these figures. The correctness of these remarks must be evident to the reader if the explanations in the previous examples have been understood. Again, since we have assumed that the point g not only represents the center of the eccentric, but also the center of the crank-pin, it follows that in order to determine how far the piston has moved from the beginning y of its stroke, when the crank-pin is at g we must draw a straight line through the point g perpendicular to $y\ x$, as has been done in these figures.

From these constructions we can form our answer to Example 24, namely:

Steam will be cut off, or, in other words, suppression will com-

mence when the piston has traveled 19⅛ inches from the beginning of its stroke, and steam will be admitted into the cylinder during the time that the piston travels through this distance. The steam will be released when the piston has traveled 22⅜ inches from the begin-

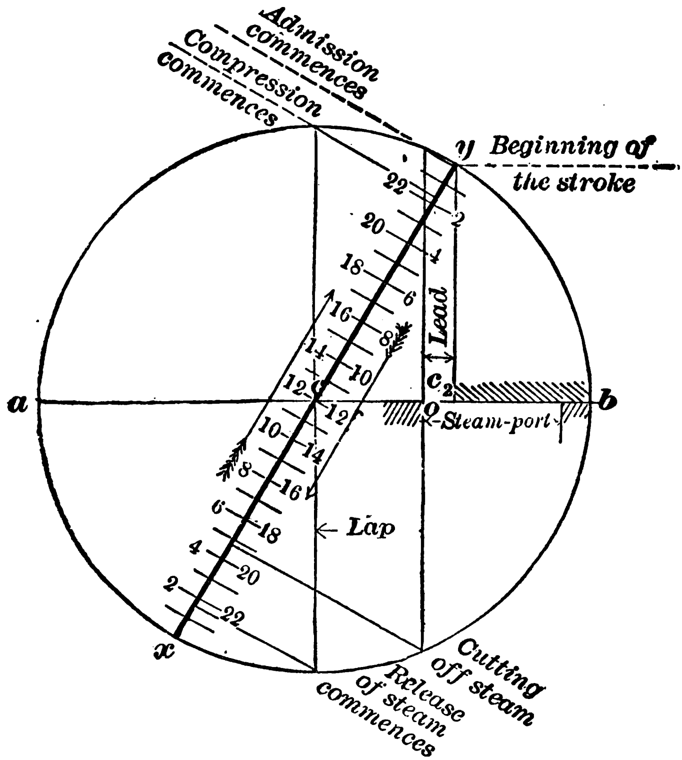


Fig. 30.

ning of its stroke, consequently the steam will be worked expansively during the time the piston travels through 3¼ inches. The release of steam will continue until the compression commences, which will occur when the piston has traveled 22¼ inches of its return

stroke. The compression will cease and the admission of steam commence when the piston has traveled $23\frac{7}{8}$ inches of its return stroke.

The same answer to our example could have been obtained with less labor by a construction as shown in Fig. 30, which is nothing else but a combination of the three preceding figures; the methods of finding the different points in Fig. 30 have not been changed, and therefore an explanation in connection with this figure is unnecessary.

THE ALLEN PORTED VALVE.

The Allen ported valve which has the supplementary port above the exhaust arch, was designed to overcome the defects of the plain slide valve. With the plain slide valve it is impossible to secure a full boiler or steam chest pressure at the

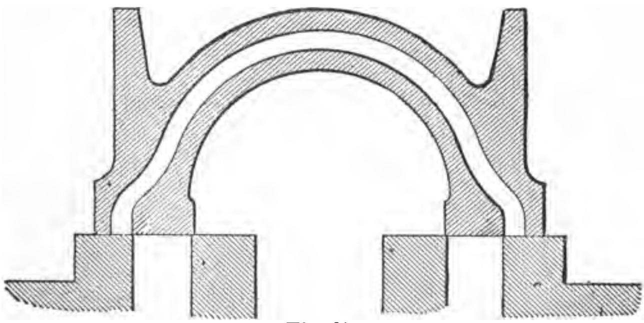


Fig. 31.

beginning of a stroke, where it is most needed, without giving excessive lead which would produce a premature cut-off and impair the other operations of the valve. Besides it was found impossible to maintain a full boiler pressure during the whole period of admission, when steam was cut off short and working at a high speed. To obviate this evil, and to lessen wire drawing, the Allen valve was designed, with a supplementary port above the exhaust arch, by which steam is received from both sides of the valve at the same time to supply the same steam port, therefore giving twice the amount of opening a plain valve would have with short cut-offs. We will first call the reader's attention to Fig. 31, which shows the valve in its central position upon the valve seat. You will observe that both steam ports are completely closed, the same as with the plain slide valve, therefore the point of release or compression will not be affected unless the lead is changed, when they will take

place either earlier or later in the stroke. We will next call your attention to Fig. 32. Here we find the valve moved off its central position and you will notice that one of the steam ports is receiving steam from each side of the valve at the same time, as indicated by the small arrows; you will also observe that the steam edge of the valve and the edge of the supplementary port open simultaneously, so they must therefore cut-off at the same time. This valve is very efficient for a high rate of speed where the travel and point of cut-off are very

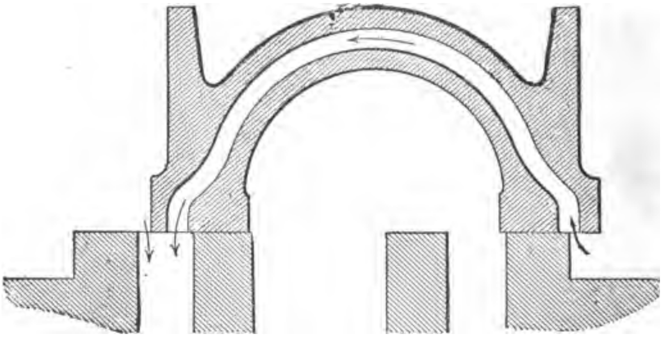


Fig. 32.

short. It maintains the initial pressure and the pressure during the whole period of admission is more uniform. These valves are in general use upon passenger engines, but the face of this valve being reduced will wear very fast when not balanced, but it usually has the Richardson balanced strips in connection.

THE HOLT SLIDE VALVE.

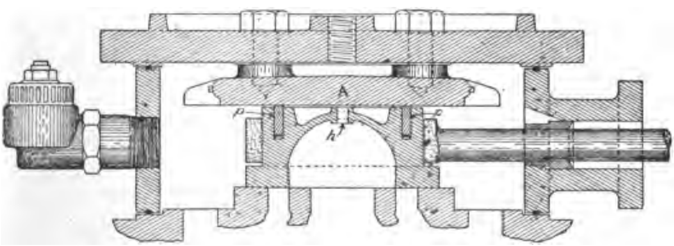
The Holt slide valve with cut-off plate, designed for use upon locomotives is at present being introduced into this country. It is a product of 1895, and was invented by Mr. Holt, of England. The valve has ports on top like the ordinary cut-off valve, but the cut-off plate has no separate eccentric or other means of positive movement. It has a space of ⅜ of an inch for travel, and lays loose on the top of the slide valve. The quick movement of the valve is supposed to shift the plate at each end of the stroke alternately, and thereby secure an earlier cut-off, without increasing the compression. Fuel economy is the claim made for it.

Balanced Valves.

The great aim of designers in constructing a slide valve for a locomotive is to produce a valve that will require as little power as possible to move it. The enormous pressure on top of a slide valve increases the friction to such an extent that it was found almost impossible for one man to reverse an engine with the large slide valves which our modern engines require; besides they were constantly cutting the valve seat. To lessen this friction what is known as the "Roller Valve" was first invented. It was a plain slide valve with rollers attached to each side of the valve; while this valve required less power to handle it, yet it failed to remove the cause of the great amount of friction, and therefore did not come into general use, although it is still in use on some roads. But when the balanced valve, sometimes called the equilibrium slide valve, was invented the correct principle seems to have been followed, namely, the removal of the steam pressure on the back of the valve. These valves have been universally adopted, they are of various forms (a few of which are here shown), but they are all made upon the same principle.

THE RICHARDSON VALVE.

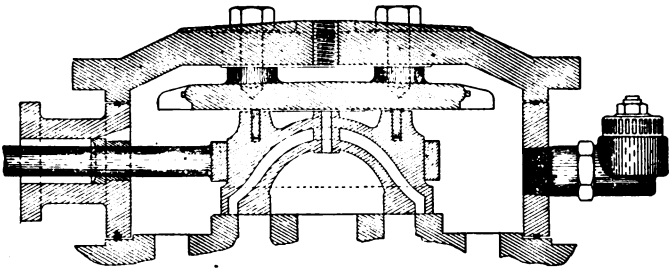
This illustration shows a sectional view of the valve in the steam chest; the balance is secured by four flat gibs fit into its



top; they are indicated on the diagram by the letter p. These gibs or balance strips are held firmly against the pressure plate by flat elliptic springs. This form of balanced valve needs little introduction as they are in use on a great many of our best roads.

THE ALLEN-RICHARDSON VALVE.

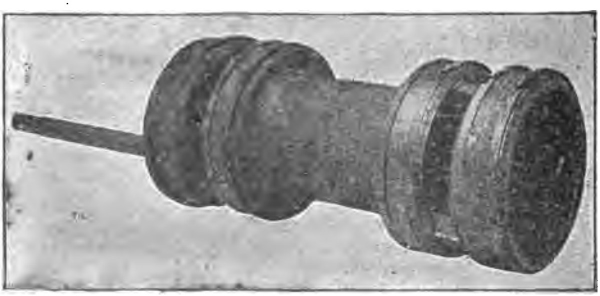
We have already shown the Allen Ported Valve and Richardson form of balance. As will be seen by the illustration,



this valve combines both improvements and it is then called the Allen-Richardson Balanced Valve. This form of valve is in use upon many of our best passenger engines.

THE PISTON VALVE.

There appears to be a growing tendency among locomotive builders of the present day to adopt the piston valve, which

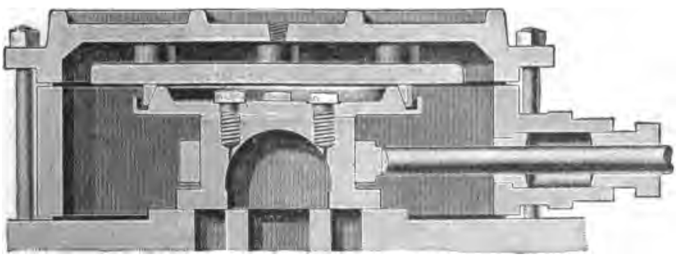


is a slide valve of cylindrical form. It has many good qualities, being almost a perfect balanced valve, and it gives a greater port area and occupies less space than the D slide

valve, and reduces the clearance which is so wasteful on steam, since for each stroke of the piston this unoccupied space must be filled with steam, which in no way tends to improve the engine, but rather decreases the expansive force, and increases the amount to be exhausted on the return stroke. The two valve faces are located near the ends of the cylinders and are either in one casting or connected with a rod or tube. These valves are used on both compound and single expansion engines, as may be seen by referring to pages 279 and 287. The illustration we have shown is the form used with the Vauclain, or Baldwin system of compounding—it is a combination piston valve, the two ends of which control the admission and exhaust of steam to and from the high pressure cylinder and the inner rings perform the same functions for the lower pressure cylinder.

THE AMERICAN VALVE.

The American Balanced Valve, of which we have shown a cut, is also well and favorably known to most of our readers.



The improvement of this balance over other balanced valves of similar pattern is the beveled ring, which is self-adjusting and needs no spring.

THE GOULD VALVE.

What is known as the Gould Balanced Slide Valve for locomotives, is something entirely new in the line of balanced valves. The principle of this valve is similar to that of the piston valve and it can be applied to the ordinary flat valve seat. The balancing is obtained by means of a semi-circle balance plate fitted into the steam chest lengthwise. It is not bolted to the cover like most other pressure plates, but rests on the valve seat. It has lugs which are closely fit on the ends to prevent it from moving lengthwise; while the pressure on its back holds it down. The top of the valve is also a semi-circle in form, slightly smaller than the plate; and has balanced strips set into it which bear against the plate in the usual manner. A small port at each end permits live steam to enter between the valve and the pressure plate, which is permitted to cover sufficient area to overcome the back pressure in the cylinder thereby obtaining almost a perfect balance. In construction the two balance plates (one for each valve), are first planed off on the edges, then the two are clamped together and bored out to the required size. The valves are finished in a similar way; first the faces are planed off and then clamped together and turned off in a lathe, and made a little smaller than the pressure plate. When the valves require facing the same amount is taken off the bottom edges of the pressure plate, thereby retaining their original positions, and the plates automatically adjust themselves to any inequality due to the wear of the valve. With·all, it is an ingenious devise which promises good results. Experiments are now being made with it on Eastern roads.

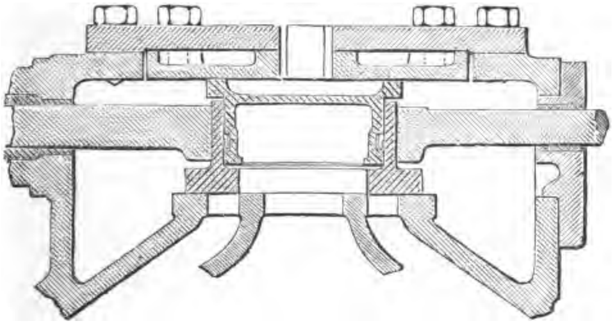
THE MUDD VALVE.

The Mudd Balanced Valve, which is the standard valve used on the Wabash system, is constructed on the same principal as the McDonald valve, about the only difference being that the solid disc shown fits on the outside of the valve instead of the inside, asbestos packing making the joint between the disc and the valve, and four small coil springs holding the disc up against the pressure plate.

THE McDONALD VALVE.

The points of advantage in this valve are as follows: That the pet cock on top of steam chest cover is always open to the atmosphere, so that should the joint leak the engineer

would see the steam escaping through the pet cock, which is sure evidence that the valve needs attention; he can then close the pet cock, and the valve will work the same as a simple D valve. The U shaped packing strips maintain a satisfactory and tight joint, and the flat steel spring beneath



the valve is of the simplest form. This valve has recently been introduced into this country. Mr. McDonald, the inventor, is a mechanical engineer at Yokohoma, Japan, and has had these valves in service some two or three years, and it is claimed they are giving excellent results.

THE MARGO VALVE.

The Margo balanced valve was one of the first forms of balance valves. It had two small discs and small packing rings (similar to air pump packing rings); the steam pressure holding the disc up against the pressure plate. Much trouble was experienced with this form of valve, owing to a gumming up of its parts which would cause the disc to stick. Very few of these valves are now in use.

POWER REQUIRED TO MOVE A VALVE.

To determine the power required to move a valve multiply the area of the valve face by the steam pressure upon it less 1-3 allowed for back pressure from the steam port and exhaust port. The friction between two smooth surfaces well lubricated varies from 1-10 to 1-14 of the pressure (the weight of the valve being so slight it is seldom considered. Friction is the resistance which two contracting surfaces have to being moved one over the other, and is of three kinds: Sliding,

rotation, and liquid.) For example: If a valve face measures 10x20 with 120 pounds' pressure, proceed as follows:

10x20 = 200x120 = ...24,000
8,000 less one third,

Divided by the friction, 10....16,000 1,600 lbs. power required.

This is an enormous strain on the valve gear which will cause it to wear rapidly. Of course this amount of power is not required of the engineer to reverse the engine, it is reduced according to the principles of leverage. Yet the power required of him is unnecessarily great. For the benefit of the reader we herewith give the proportions used by the American Balance Valve Co. for balancing their valves.

FORMULA.

AREA OF BALANCE FOR PLAIN VALVES.

Area of ONE steam port TWO bridges and the EXHAUST port PLUS 8 per cent if for SINGLE balance and PLUS 15 per cent if DOUBLE balance.

EXAMPLE FOR SINGLE BALANCE.

S. port 1¼″+ Bridge 1″+ Ex-port 2½″+ Bridge 1″= 5¾″x16″. 5¾x16=92°; 8% of 92=7.36; 92+7.36=99.36°=Area. Nearest dia. for 99.36 = 11¼ = Dia. for Ring.

EXAMPLE FOR DOUBLE BALANCE.

S. port 1¼″+ Bridge 1″+ Ex. port 2½″+ Bridge 1″= 5¾. 5¾x16 =92°; 15% of 92=13.80°; 92+13.80=105.80°=Area. 105.80÷2= 52.90, or Area of each ring. Nearest dia. for 52.90=8¼ dia. for EACH ring.

ALLEN PORTED VALVES.

For ALLEN valves use same Formula as above; then from the Area derived subtract the area of ONE side of the ALLEN port. Example: 1½″+ 1⅜″+ 3″+ 1⅜″ = 7¼″x17″= 123.25°+ 15% = 141.73° Allen port = ½x17 = 8½; 141.73—8.50 = 133.23°÷ 2 = 66.61 = area at each Ring.

HOLE IN THE TOP OF BALANCED VALVES.

You will notice there is always one or more small holes drilled through the top of all balanced valves. This hole is absolutely necessary, as it permits the steam which leaks through the strips, or rings, to escape through the exhaust. Without this hole the valve will lift off the seat, and the steam which would leak through the strips would practically nullify the good qualities of the balanced valve.

THE VACUUM RELIEF VALVES.

When a locomotive is running and the steam is shut off, a partial vacuum will be formed in the steam chest, causing the valve to chatter and thus ruin its mechanism, besides drawing cinders into the steam chest. To overcome this evil a vacuum relief valve is used with all balanced valves, and should be used with the plain slide valve. It admits air into the chest when the steam pressure is shut off and thereby prevents a vacuum being formed. No balanced valve must be expected to work satisfactorily without a vacuum relief valve.

LINK MOTION.

The shifting link is acknowledged to be the greatest mechanical invention of the nineteenth century. When we take into consideration the fact that for more than fifty years the brightest minds and the most skillful mechanics of the whole world have been trying to improve or replace the link motion without apparent success, we begin to realize the importance and appreciate the value of this invention to the whole human race. It is true a few improvements have been made upon it, but the original principle, or frame-work of link motion remains unaltered.

INVENTION OF THE LINK.

Mr. Sinclair, in his work, says: "There is no doubt but the link was invented by William T. James of New York, a most ingenious mechanic who also invented the double eccentrics. He experimented a great deal during the period from 1830 to 1840, and while his work proved of no commercial value to him, it is probable that Long, who started the Norris Locomotive Works at Philadelphia, and introduced the double eccentrics, was indebted to James for the idea of a separate eccentric for each motion. The credit of inventing the shifting link is due to William Howe of Newcastle, England. He was a pattern maker employed by Robert Stevenson & Co., and he invented the link in 1842 in practically its present form. Howe's idea was to get out an improved reversing motion. He made a sketch of the link, which he explained to his employers, who were favorably impressed with his idea, and permitted him to make a pattern of it, and afterward gave it a trial on a locomotive constructed for the Midland Railway Company. It proved successful the first day. Although Stevenson gave Howe the means of applying his invention, Howe failed to perceive its actual value, for it was not patented. Seeing how satisfactorily it worked Stevenson paid Howe twenty guineas (one hundred and five dollars) for the devise, and secured a patent in his own name. This is how the shifting link comes to

be called the "Stephenson Link." The credit for this invention was not extravagantly paid for.

VALUE OF THE SHIFTING LINK.

Several other reversable motions have been invented by Joy, Walschaert, Allen, Stevens, Lewis and others, but each of them in turn failed to demonstrate their superiority over the shifting link. Its motion is capable of an accurate adjustment, which practically nullifies the effect of irregularities in the cut-off and exhaust closure, attributed to the angularity of the connecting rod, which will be explained later. Therefore it is acknowledged to be the best reversible valve gear in existence at the present day, and it is in use on most every locomotive throughout the world. So, whatever the reader may learn of link motion in this book will be found useful knowledge wherever he may go. Link motion is not the most economical valve gear, but it is the best reversible motion, and as it is necessary to have a reversible motion on all locomotives, it is in general use everywhere. The most economical valve gear is one that will admit the greatest pressure of steam into the cylinder the quickest, just when the steam is most needed, and release the quickest when the proper time arrives to exhaust. Therefore the slide valves which are in general use on the majority of locomotives, while not the most economical valves, are the only kind that can be used with link motion. The piston valve, which is gradually replacing the D valve, is also a slide valve of different form. The Cam valve and the Rotary slide valves which are used upon the Reynolds-Corliss engines are considered the most economical valves.

LAYING OUT LINK MOTION.

While there are certain points in laying out a link motion which can only be ascertained in a technical manner, yet, in ordinary shop practice almost the entire motion work is laid out by well established rules which are much easier and quicker found and equally as good for all practical purposes.

Therefore in order to show our readers wherein theory and practice differ, we will first explain the practical methods (and call attention to such points that can only be found in a technical way), and afterwards explain the correct technical manner to lay out a link motion.

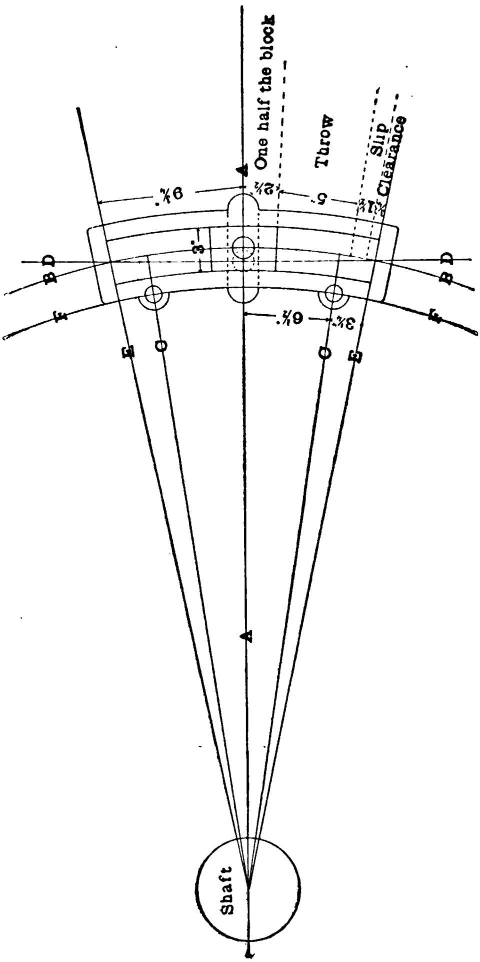
Shop Practice.

HOW TO FIND THE CORRECT RADIUS OF A LINK.

Find the exact distance between the centre of the rocker box and the centre of the main shaft or axle. To do this place a straight edge across the front of your main jaws (providing the front jaw is square with top of frame); and drop a line through the centre of your rocker boxes, and find the exact distance between the straight edge and the line. Now add to it one-half the diameter of your main driving box and thickness of your shoe, which will give you the correct radius. If both main jaws taper, find centre of jaw (see Shoes and Wedges, page 140), and find distance from centre of jaw to line dropped through rocker box. This rule applies for straight rockers only. If rocker arm has a backset, subtract the amount of backset from this length and the remainder will be the correct radius. Some manufacturers of locomotives make the link radius ¾″ per foot less than this length, but the Master Mechanics at one of their conventions decided the method we have explained to be correct.

HOW TO LAY OFF A NEW LINK.

We will presume the throw of the eccentric to be 5″ and that the link block is to finish 5″ long and 3″ wide. Make the straight line A, then with a length equal to the correct radius of the link, describe the arc B. Now add together 2½″ for one-half the length of the link block, 5″ for the throw of the eccentric, 1½″ for the slip of the link block (see Slip of Link, p. 60); and ¾″ for clearance at the end of the link. (In shop practice 1½″ is the amount usually allowed for the slip, and ¾″ for clearance.) We have a total of 9¾″, which is one-half the length of the link inside. All measurements must be made on the arc B, so if you have a flexible scale, mark off 9¾″ each way from the point where A and B cross; if you have not, cut off a narrow strip of tin 9¾″ long. Now from these two points draw the lines marked E, through the centre of the shaft, these lines indicate the inside ends of the link. Now add together 2½″, which equals one-half the length of the link block and ¾″, which is the clearance; this amounts to 3¼″;


One half the block
Throw
Slip
Clearance
Shaft
A
A
B D
B D
F
F
E
E
C
C

so this distance from each end of the link must be the position of the centre of the link block in full gear; therefore from the two points where lines E and B cross, lay off two other points 3¼", and from these two points draw the two lines marked C. The link pin holes will be laid off on these two lines, C, which indicate full gear. Now the link block is to be 3" wide, so add 1½" to the length of the radius and lay off the front face of the link inside and the front face of the block. Now subtract 1½" from the radius and lay off the back face of the link inside and the back face of the block. Now the block is to finish 5" long, so from the point where lines A and B cross, with a length equal to one-half the length of the block, which is 2½"; lay off two other points on the arc B, and from these two points and through the centre of the shaft, draw the two lines which indicate the end of the link block. The link pin holes must be an equal distance from the radius, and as close to the radius as possible, to avoid increased slip. Therefore describe the arc F (which is called the link pin arc), as near the arc B as consistent with a proper thickness of the link. Now the link pin holes must be laid off at the two points where the lines C cross the arc F; now through the two points where the lines E cross the arc B draw the straight line D. In shop practice the point where the lines A and D cross is used as the centre of the saddle pin (we have shown it and outlined it with dotted lines). This point is only approximately correct, but near enough for all practical purposes. To find the correct point of suspension see (Technical Points page 83). The off-set of the link saddle pin is therefore indicated by the distance between the lines B and D, where they cross line A. All dimensions shown indicate the correct measurements on the arc B, excepting the width of the link block.

REASON WHY A LINK SADDLE IS OFFSET.

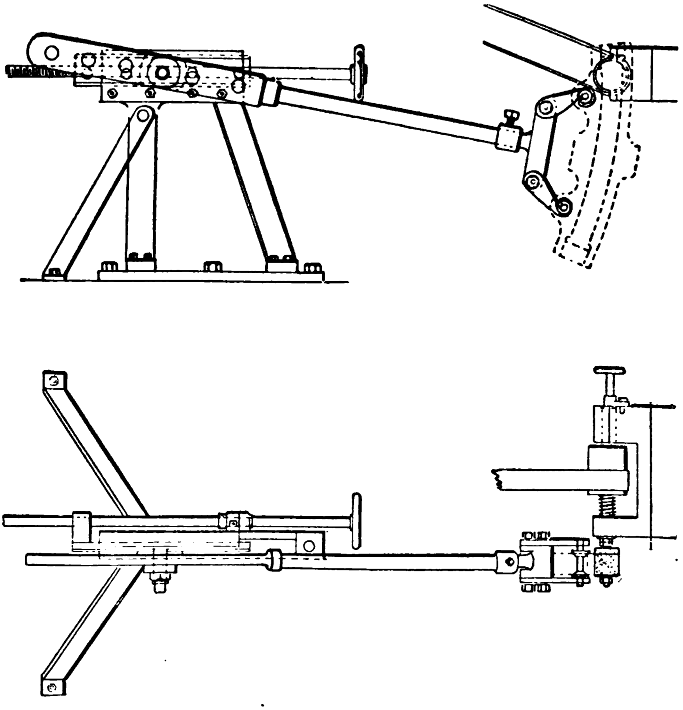
The offset in the link saddle is to obtain as nearly as possible an equal cut-off, and at the same time permit the lead to be the same at each end, and to approach as nearly as possible a correct distribution of steam with a reciprocating engine and slide valve. It is done to overcome the inherent imperfection in the design of links and the angularity of the main rods.

SLIP OF THE LINK.

What is known as the "slip of the link" is one of those nice points of mechanism that is understood by very few machinists, and yet it is not at all mysterious, but only requires

a little diligent study. Link motion is specially characterized by this very important feature, that of adjustability, in addition to the other two motions. The link block being securely fastened to the bottom of the rocker arm, must move in the arc traversed by the arm, while the action of the eccentric rods on the link forces it to move in a sort of a vertical motion at certain parts of the stroke, which causes the link to slip on the block. The link slips most when in full gear, and the slip diminishes as the block is moved toward the centre of the link. By referring to Technical Points, page 73, you will note the distortions introduced into the valve's motion by the angularity of the connecting rods. While moving the link saddle pin back tends to equalize the motion, it also tends to increase the slip, which, if very great, would seriously impair the valve's motion. On marine engines they sometimes sacrifice equality of steam to the reduction of the slip, but with the long connecting rods used upon locomotives, little difficulty is found in keeping the slip within practical bounds. Raising the saddle above the centre of the link will also equalize the valve's motion, but in locomotive construction there are practical objections to doing this. Back-setting the link saddle pin has an effect equivalent to a lengthening of the eccentric rod during a portion of the stroke; thereby equalizing the valve's travel. Moving the eccentric rod pin holes farther from the radius of the link, or closer together, tends to increase the slip, so they should be laid off in their proper places. You will notice by the accompanying sketch that we allow 1½″ at each end in the length of the link for the slip of the link. The amount of slip varies on different engines, but in machine shop practice 3″ is considered a safe margin. If you will place the reverse lever in the centre notch and go under the engine and watch the link and block just as the pin passes either center, you will see that when moving forward the block will slip down in the link about 1½″ without apparently moving the rocker arm any, and when moving backward the block will slip up the same amount. If you will consider the position of each eccentric to the crank pin, you know when the crank pin is on either centre, one eccentric is traveling forward and the other backward, and each traveling at the same speed. The link must move but the block does not, therefore the slip. The amount of slip may be ascertained by measuring from the end of the link, in each of its positions, to the point in the centre line of the link at which it is intersected by the centre line of the motion; the difference between the greatest and least of the dimensions so obtained being the amount of the slip. To increase the length of the link increases lead toward mid-gear.

To decrease the length of the link diminishes increase of lead toward full gear, but increases the slip. Auchinloss, who is recognized authority for designing link motion, mentions four alterations capable of reducing the slip when too great, viz.: Increase angular advance; reduce travel; increase length of link, or shorten eccentric rods.



LINK GRINDER.

The cut above shows the form of a very neat, simply constructed anu valuable link grinder, which is in use in one of our large railroad shops. A small emery wheel is used and it can be adjusted to suit any radius.

TO GET LENGTH OF LINK HANGER.

When possible, plumb outside arm of rocker and plumb link and outside arm of tumbling shaft; then get exact distance from center of short arm on tumbling shaft to center of pin on link saddle. This will be your length. If ordering new work, make drawing as above. (We presume top arm of tumbling shaft is to stand central or plumb.)

HOW TO PLANE A LINK AND BLOCK.

Most shops have one small planer equipped with an adjustable radius plate which fastens onto the bed of the planer. Clamp the link or block onto this plate, keeping it set to the correct radius. Then adjust planer head to either side to prevent the tool from dragging—same as for taking a side cut on other work—then proceed in the usual manner.

HOW TO FIND THE TRAVEL OF A VALVE.

We will presume the width of the steam port is $1\frac{1}{4}''$; the lap $\frac{7}{8}''$; find the travel. If the valve is to open the steam port fully and no more, for the admission of steam, then the travel can not be less than twice the sum of the width of the steam ports and lap. Hence, in our example we have, $1\frac{1}{4}+\frac{7}{8}=2\frac{1}{8}\times2=4\frac{1}{4}$ inches—travel of the valve. If the valve has over travel (most all locomotives have) and is to move, say $\frac{3}{8}''$ beyond the steam port, then we have $1\frac{1}{4}+\frac{3}{8}+\frac{7}{8}=2\frac{1}{2}$, and $2\frac{1}{2}\times2=5''$ travel of the valve. When the rocker arms are of equal length, the throw of the eccentric is equal to the travel of the valve. You can find the travel approximately correct by adding together the width of one steam port, the outside lap, and one-half the width of one bridge, and double the entire amount. (See chapter on the Slide Valve, page 36.)

HOW TO FIND THROW OF ECCENTRIC.

If both arms of rocker are of equal length, the throw of an eccentric should be the same as the travel of valve. If arms of rocker are of different lengths, you will need more or less throw, according to the distance the bottom arm must move, to move the top arm the required amount of travel.

Another way is to measure the least distance between the bore and the outside face, then measure the greatest distance between the bore and outside face. The difference will equal its throw. The distance from the center of the bore to the center of the eccentric is sometimes called its throw.

LENGTH OF ECCENTRIC BLADES.

Find the exact distance, on a horizontal line, between the center of the shaft or axle, and the center of the rocker box. Subtract the backset of the rocker arm, if any, and the remainder will be the length from the center of the eccentric strap to the center of the link. Now subtract the distance from the center of the link pin hole to the center of the link, and also the distance from the center of the eccentric strap to shoulder on strap for the blade. If you have an adjustable blade subtract ¼″ more for clearance at the shoulder. The remainder will be your length from center of link pin hole to end of blade. This length is only approximately correct, but it is near enough for all practical purposes, as the blades are almost always adjusted when setting the valves. The technical length would vary only slightly. It would be a trifle longer as the blades are crossed when the pin is on back center, while they are not crossed when the pin is on forward center, which tends to shorten the blade. (See Technical Points.)

HOW TO LAY OFF AND TURN UP A NEW ECCENTRIC.

Fasten the two halves together, put a wooden center (with tin fastened on its face) in hole for shaft, parallel with rib of eccentric. Find center of hole for shaft, keeping the center on line with planed face of the two halves. Now scribe a line through center of rib, and center in hole for shaft. Set dividers to one-half the throw eccentric should be; put dividers in center for shaft and scribe a line across line extending through rib. The point where the two lines cross is the center of your eccentric, so scribe a circle, the size the eccentric should finish outside, and another from other center the exact size of your shaft or axle. Now clamp planed side of eccentric to face plate of lathe, setting true with small circle, and bore out to fit shaft. First fasten a weight on face plate, opposite center of eccentric, to counterbalance lathe. Now, if you have a regular eccentric chuck with mandrel attachment, put your eccentric on it and set to large circle. If not, put it on a mandrel and make centers for lathe one-half the throw from center of mandrel, and finish to required size outside diameter, and use a gauge, if you have one, for collars.

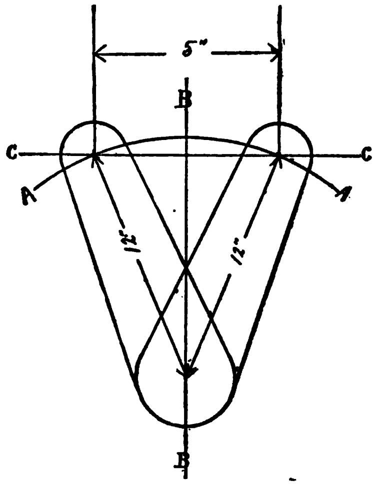
Hole for shaft should be bored just large enough to turn freely when tightened on shaft.

HOW TO BORE OUT ECCENTRIC STRAPS.

Put about ¼″ liner between the two halves to allow for closing. Clamp to your face plate and bore out about 1-64″ larger than eccentric, with heavy bearing on crown and light bearing on collars; allow 1-32″ lateral between collars.

TO GET LENGTH OF ROCKER ARMS.

Get exact height from top of frame to center of rocker box, and exact height from top of frame to center of stuffing box



on steam chest. Take the difference between the two, say 12″, and use that length temporarily and make sketch as above. We presume the valve travels 5″.

Find the distance between the two points where lines A and C cross line B, say it measures ¼″; then add ⅛″ to length of arm, which would make 12⅛″ for outside arm.

Now, to get length of inside arm, figure on the throw of your eccentric, and find out how long bottom arm would have to be to move the top arm 5″.

HOW TO LAY OFF AND FINISH ROCKER ARM.

Place arm on two V blocks, on face plate. Use surface gauge to get both centers, and try body of rocker and see if it will finish required size.

Then try two foot square with arms, and see if they are square with your centers, and if they will finish required size all around; also try boss on end of each arm and see if they will finish required size; if so, drill small hole in each center to retain original center, and put in lathe. But if it will not true up, have blacksmith alter it. Now, when you have it in lathe, turn up body (or bearing) to required size, then cut down center of bearing about 1-32" smaller than outside bearing, for about three inches. That will give the oil a better chance to spread and prevent too large a bearing. Now get exact distance between shoulders inside, and finish inside of each arm. Then outside face of both arms may be finished on slotter, jumper or lathe. If you finish outside of arms in lathe, keep arms to the required thickness, and face off each boss to required thickness, and cut a small groove on each outside face, to find center with afterward.

Now lay off holes in each end of arms and have drilled small enough to allow for taper reamer.

Now put rocker in boring mill, use two centers to clamp it, keep each center exact height from bed of boring mill, and perfectly square with boring bar.

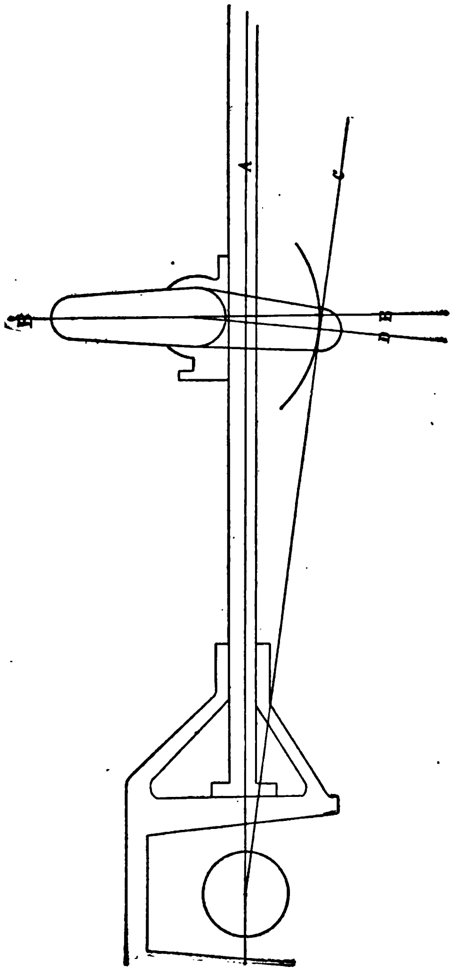
Now use taper reamer and ream out to required size; then finish outside of each boss with tool in end of boring bar; then take to planer; clamp on V blocks, or parallel strips, and plane off edges of each arm to required size.

Now take to your vise and chip off the corners beneath each boss, where tool would not finish. Now file and polish with emery cloth until finished.

TO GET BACKSET OF STANDARD ROCKER ARM.

To find correct backset of a rocker arm you should lay it off on a large face plate or finished board. First make line A, then measure from line A to bottom center of rocker, when inside arm is plumb. Make line B at right angle with line A; set dividers in circle where A and B cross and scribe a line down on B the distance from center in bottom arm to line A; then make line C from center of shaft through the center on line B.

Now use square from line C through center of rocker arm, and make line D. Now get distance from where D crosses C to where B crosses C, which is your off-set. If the center


A
C
E
D
E

of the hole in the bottom arm of the rocker was parallel with the wheel centers on line A then the rocker would need no backset, as the line A would then be the center line of motion. (See page 77.)

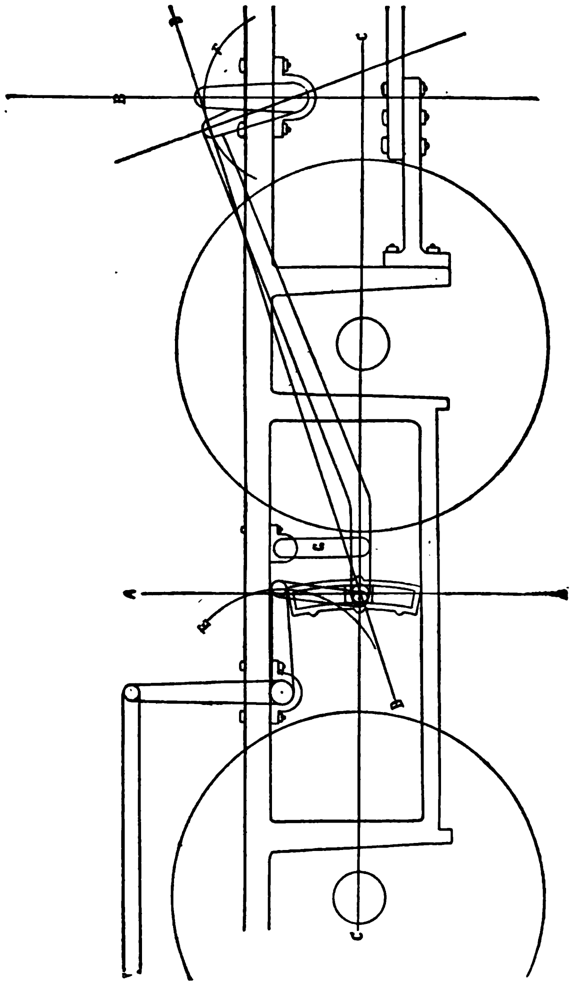
TO FIND BACKSET OF DIRECT MOTION ROCKER ARM AND LENGTH OF EXTENSION ROD.

This requires close figuring and considerable work. You had better make a drawing to a scale, or else lay it out on a large face plate or planed board making each part its exact size. First make the square lines A and C and B, set the top arm of the tumbling shaft plumb (provided that is its central position); now you must know the central position of the link in relation to the tumbling shaft (see Technical Points, page 85); now the center of the link block should be placed where the lines A and C cross. The line A being the proper distance from the center of the tumbling shaft stands. Now with a radius equal to the length of the inside arm of the rocker describe the arc F. Now through the center of the link block draw a straight line tangent to the arc F, and from the line D draw a square line through the center of the rocker box; the distance from this line to the center line B will indicate the amount of backset required, and the distance from the center of the inside arm thus found, to the center of the link will be the length of the extension rod from center to center, the small hanger marked G holding the link block stationary. We therefore work from the center of the link block instead of the center of the axle; therefore the line D is the center line of motion

In practice if one of these extension rods gets bent or broken the length is usually taken from the other extension rod, or if both are bent or broken you can determine their original length when setting the valves.

HOW TO FIT A ROCKER ARM INTO A ROCKER BOX.

If a new rocker and new box, bolt the two halves of the box together tight, then bore out the box about 1-128 part of an inch larger than diameter of rocker, and fillet each end; then take apart; take tool marks off with a scraper; chip or file groove for oil and you are done. If it is an old rocker and box, true up bearing on rocker in lathe or with smooth file; plane off face of rocker box to allow for closing; rebore or fit to good bearing with file and scraper, and line it as close as possible. See that top arm will move free for 6″, or travel of valve.



RELATIVE POSITION OF LIFTING SHAFT AND ROCKER, AND LENGTH OF LIFTING SHAFT ARMS.

These are technical points, and any attempt to determine them by plain measurements would result in a failure. (See Technical Points, page 85.)

HOW TO FINISH AND TRY TUMBLING SHAFTS.

If all the arms fit and key onto shaft, bore out and face off the arms in drill press or boring mill. If solid arms, turn bearings in lathe, or clamp on boring mill, and turn off bearings to required size. Then clamp the shaft in a pair of centers and keep perfectly true with boring bar, and drill, bore out and face off holes in end of short arms. Have hole in long arm finished at drill press, or finish ends before welding.

If an old tumbling shaft, turn up bearing on boring mill and put bushings in tumbling shaft stands. Then take tumbling shaft to face plate, put centers inside of holes for short arms. Then use surface gauge and try those two centers with the two centers in the end of shaft, and keep all four centers perfectly true with each other; then use a square on faces of short arms where link hangers fit onto.

HOW TO LEVEL UP TUMBLING SHAFT AND ROCKER ARMS.

Place a straightedge across the frames and level it by cylinders. Then try the two centers in your tumbling shaft arms and see if they are true with your straightedge. Then try the two centers in your rocker boxes. If not right, line them up until they are right.

CAST STEEL TUMBLING SHAFTS.

Tumbling shafts are now being made of cast steel, the shaft and all the arms being cast in one solid piece. It is claimed they are much cheaper than a forged shaft, and overcome the possibility of being troubled with loose arms, and can be worked in a blacksmith's fire if necessary.

LENGTH OF REACH ROD.

If your reverse lever is straight, and top arm of tumbling shaft can be made to stand plumb, get distance between center of foot casting of reverse lever and center of tumbling shaft

stand. If not, plumb reverse lever and set top arm on tumbling shaft where it must stand when central, and get distance between holes.

QUADRANT.

To find its Length.—This is usually ascertained when designing the engine; but if not, find out how far the center in the top arm of the tumbling shaft will travel while the center of the short arms travel twice the amount of the throw of your eccentrics.

Now find the distance between the bottom of the reverse lever latch (when drawn up) and the center of the bottom hole in lever for reverse lever casting. Now find the distance between the center of hole for reach rod in reverse lever and the hole in the bottom end of lever.

Now you have those two lengths and you know the center of the hole where the lever fastens to the reach rod must travel exactly the same distance as the top arm of the tumbling shaft. So find out how far the latch will travel while the hole for reach rod travels the required amount. Figure it, or lay it off on the face plate.

Now add the width of your reverse lever, your clearance, and enough stock to fasten at each end.

To Find Radius.—Get the exact distance from the center of the bottom hole in the reverse lever to the bottom of the reverse lever latch, when it is drawn up. Make the radius 1-16″ shorter to allow for clearance.

To Fasten.—If the quadrant fastens to the boiler as most of them do, and the boiler is cold when you are laying off your holes, let the latch clear the front end of the quadrant about 1-32″ and the back end ¼″ when the latch is drawn up; that will allow for the expansion of the boiler.

Slot to Radius.—Most slotters are supplied with extension braces which fasten onto circle bed of slotter, so you can set quadrant to any radius desired. Run table away out from tool, fasten braces on the inside and put a steady rest on bed of slotter.

If you have no extension you must feed by hand, although an extension could be rigged up in a few minutes.

If you have none, slot and file to true circle.

LENGTH OF VALVE STEM AND ROD.

Get distance from center of outside arm of rocker (when plumb) to center of exhaust port. This gives length of valve stem and valve rod both, from center of hole in end of valve rod to center of yoke.

Now to get the length of the stem. Get distance from center of steam chest to outside face of chest or joint; now add the length of your gland studs to length of gland, or that part of the gland which goes on the stud, and add to this one-half the extreme travel of the valve. This will give the distance from center of yoke to shoulder on stem. Subtract this from the total length of both and you have the length of your valve rod.

HOW TO MARK PORT OPENINGS.

First—See that valve stem is connected onto the rocker arm and valve stem key tightened. Now see that valve is not cocked and is perfectly square with the port. If not, use small screw jack and spring it until true with port openings. Now see if there is any lost motion in valve yoke and valve. If so, put in all the liners you can (to take up lost motion) back of the valve, and set valve so you can just slip a piece of thin tin into front port openings; then put center punch marks on cylinder, and mark front port mark with valve tram.

Now put liners (to take up lost motion) in yoke, in front of valve between valve and yoke, and set valve to back port opening same as in front, and mark stem again. Now use a box square and draw a line through both port openings on valve stem, and put a small center on each line where lines cross, and use small dividers and get center between port marks on stem, and make another small center. Now you have finished; you have your port marks.

Technical Points.

As previously stated, we will now explain the correct technical manner of finding those points which could not be explained by plain measurements in the foregoing chapter. They are:

First—The angularity of the main rod showing the crank pin at full and half stroke, on a straight line engine.

Second—The position of the crank pin at full and half stroke on an engine whose cylinder axis is above the wheel center.

Third—Relative position of the eccentrics to the center line of motion.

Fourth—Relative position of crank pin and eccentrics at full and half stroke.

Fifth—How to find the correct length of eccentric blades.

Sixth—How to find the point of suspension, which indicates the position of the center of the saddle pin.

Seventh—The relative position of the tumbling (or lifting) shaft and rocker.

Eighth—The length of the tumbling shaft arms.

Strict theoretical rules prohibit the use of the link templet, but as it gives the same results when properly used, for simplicity we will use it in explaining this work. While some of our drawings may appear complex, we have made each as clear and plain as possible for a thorough comprehension of the subject, and in order that it may be more readily understood by all we have avoided the use of algebra and geometry. So the attentive reader will thoroughly understand each subject. The first to which we desire to call attention is the

ANGULARITY OF THE CONNECTING RODS.

The eccentric is in effect a crank, and being keyed onto the axle must always remain an unvarying distance from the crank pin. It therefore follows that any irregularities imparted by the crank into the motion of the piston, will also be imparted by the eccentric rods into the motion of the valve. The reader knows that when the crank pin is on the forward center the cross head will have reached the extreme forward travel, and when the pin is on back center the cross head will have reached extreme back travel as indicated by the short lines on the guides. See Fig. 1. It now becomes necessary to locate the position of the crank pin at half stroke. We know the length of the main rod equals the distance from the center of the axle to the center of the cross head pin, when the cross head is in mid-stroke. Therefore with a radius equal to the length of the main rod, we have described the arc A. We find that when the cross head is in the center of its travel the crank pin must be at a point where the arc A intersects the crank pin circle B, which is the path of the crank pin; and you will notice the crank pin has not yet reached the quarter when the cross head is in mid-stroke. In order to more clearly explain this subject we have placed the pin at the top quarter, and you will notice that the cross head has passed the center of its travel (which is indicated by the two lines near the center of the guides and the small center on the cross head indicates the center of the cross head). Therefore the cross head must travel a greater distance while the pin moves from

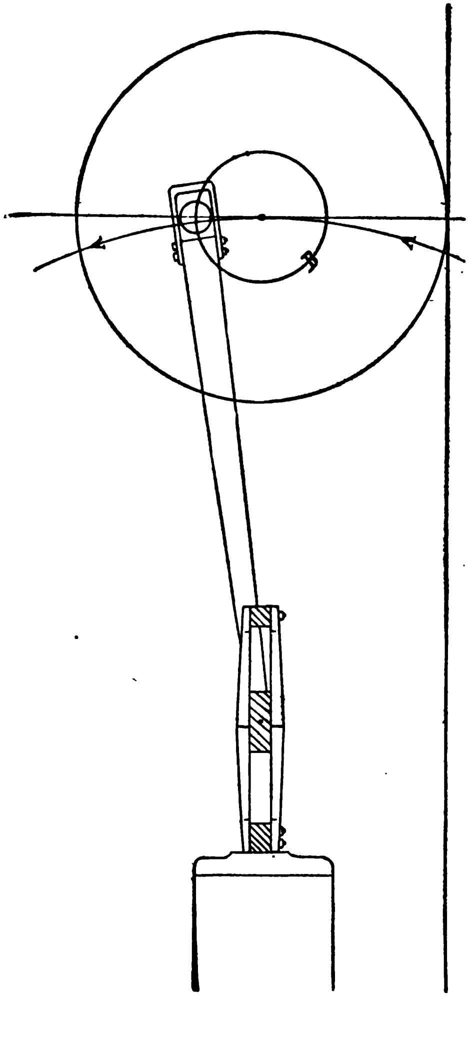


Fig. 1.

the forward center to either quarter than it does from the back center to either quarter. As we have stated, the eccentric is in effect a crank, and the imperfections introduced by the main rod into the motion of the piston are also introduced by the eccentric rod into the motion of the valve, but the throw of the eccentric being much less than that of the crank pin, and the eccentric rod being proportionately longer than the main rod, the distortions in the motion of the valve are necessarily much smaller than those of the piston, and they vanish entirely when the eccentric is on either center. To overcome this evil effect of crank motion, and in order to obtain an equal cut off, the link saddle pin is set back, which only approximately corrects the inherent error of crank motion. The shorter the main rod the greater the irregularities introduced, and vice versa.

Experiments were made by making one steam port wider than the other to overcome this defect, but that caused one exhaust to be heavier than the other and proved injurious in other ways. Valves are used upon some stationary engines which have more outside lap on one side of the valve than upon the other to offset the effects of the angularity.

The early builders of steam engines used what is known as the slotted cross head or Scotch yoke to overcome this evil, but it was found that setting the link saddle pin back answered the same purpose and was less expensive.

CYLINDER AXIS ABOVE WHEEL CENTER.

By examining Fig. 2 we discover another form of irregularity. In this case the horizontal line A L B represents the path of the cross head pin which is on a horizontal line with the cylinder center; the points A and B representing the points of extreme travel and the point L indicating center of travel. The line N O bisects the wheel centers and the line R S is perpendicular to N O, therefore the distance from C to L indicates the length of the main rod, and with its radius we describe the arc I J. Therefore the two points where the arc I J intersect the crank pin circle represent the position of the pin at half stroke; and when the cross head is at either A or B we know the main rod must be on line with the wheel center C, therefore G H indicates the positions of the crank pin when on forward or back center. On an engine of this build the length of the main rod should be obtained by height and depth measurement when the cross head is not in place. (See Height and depth measurement, page 224.) Care should also be taken when putting up an old rod or finding travel point to get the pin on its correct center.

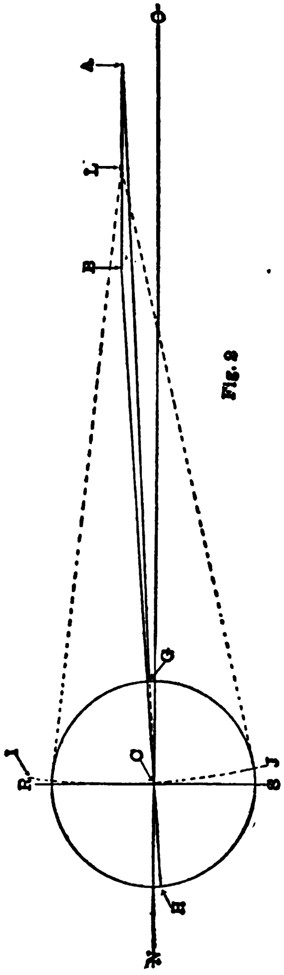


Fig. 8

CENTER LINE OF MOTION.

On all standard engines a straight line drawn through the center of the main axle, and the center of hole in the lower rocker arm when the top arm is plumb indicates the "center line of motion." In Fig. 3 we will use the square lines N O and R S the same as before. In this case we find the center in the lower rocker arm is below the horizontal line N O, therefore there must be a backset in our rocker arm which is shown. How to find the amount of this backset has already been explained, and requires no further mention here. If the center in the lower rocker arm was on the line N O no backset would be required, and the line N O would then be our center line of motion. Most modern engines are built that way—with a straight rocker arm. Remember the two eccentrics are always set at right angles with the center line of motion as shown in Fig. 3 except when the angular advance is changed for reasons which will be explained later. The distance they are located from the wheel center will be explained later; the point F indicating center of forward or go ahead eccentric and the point B indicating center of back-up eccentric, the circle E represent the outside diameter of the eccentrics, and the circle S the shaft or axle, and the inner circle represents the path of the center of the eccentrics. Now we find the crank pin on the forward center at the point G; and we find the eccentric centers are not an equal distance from the point D, which is on a line with the center of the crank pin and the center of the shaft. If we wished to locate the positions of the eccentrics when the crank pin was on the back center, we would have to find the distance from the point F to D and from B to D and transfer them from the line N O at back end to their respective positions.

RELATIVE POSITION OF CRANK PIN AND ECCENTRIC AT FULL AND HALF STROKE.

We have merely used Figs. 2 and 3 to show the reader points which must be considered on engines of different build. But in order to avoid any complex drawings which only tend to confuse, and to explain the following subjects in as plain and simple a way as possible, we will presume this is a "straight line engine" whose wheel center and cylinder center are on a horizontal line, which is also the "center of motion," having a straight rocker arm (by straight, we mean a rocker with no backset). In Fig. 4 we will use the "center line of motion" (which is the same as the line N O in Figs. 2 and 3), and the perpendicular line R S. The large circle represents the path

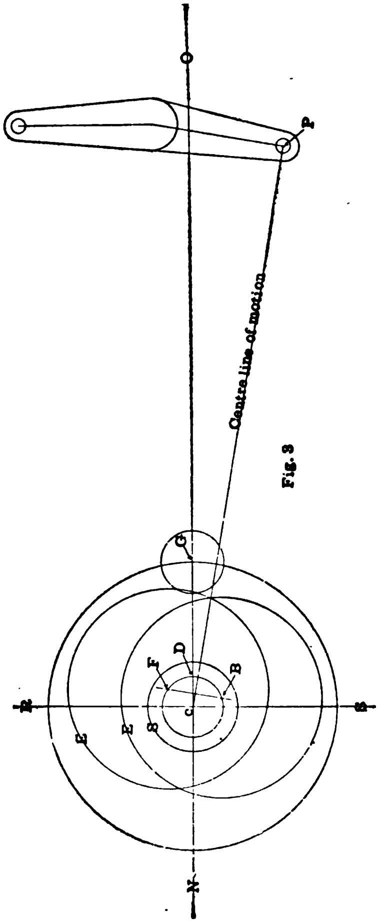


Fig. 3

of the crank pin, and the small circle the path of the center of the eccentrics. Therefore the points G H show the position of the crank pin when on forward and back center, and T W indicates the position of crank pin at half stroke (as explained by the Angularity of the connecting rod, we will therefore draw two straight lines from the points T W to the wheel center. Now locate the positions of the two eccentrics when the crank pin is at the forward center G. If the valve has no lap or lead the eccentrics would be at right angles with the crank pin, and therefore on the line R S; but we will presume the valve has ⅞″ outside lap and 1-16″ lead, therefore we must advance both

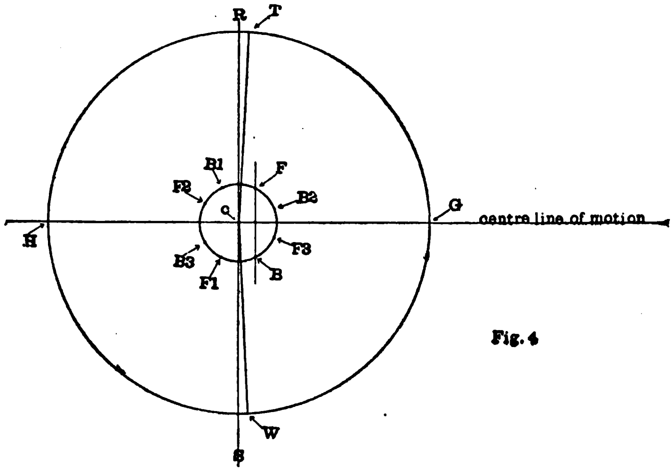


Fig. 4

eccentrics that amount toward the pin, so the valve will have the required amount of opening at the beginning of the stroke. The crank pin being at the forward center at G the piston must be at the forward end of the cylinder, therefore the forward steam port must be opened to admit steam. Now by advancing both eccentrics toward the pin it forces the bottom arm of the rocker forward and the top arm backward, opening the forward port. So make another short line parallel to the line R S and 5-16″ in front of it (which is the amount of lead and lap added together); now where this line crosses the eccentric circle will be the center of each eccentric, as shown by the letters F and B, and in this case they are an equal distance from a line drawn from C to G. The distance the center

of each eccentric is advanced from the perpendicular line R S, which must be perpendicular to the center line of motion, is called its "angular advance." We have therefore located the positions of the two eccentrics in the full stroke forward, we will now locate them in full backward stroke when the crank pin is at H; (the eccentrics are always an unvarying distance from the pin, being securely fastened to the axle), therefore they will be an equal distance from a line drawn from C to H, and they are indicated by F1 and B1. We will now locate them at half stroke, the pin being at T they will be an equal distance from the line C T and are indicated by F2 B2. We will now locate them at W. They will be an equal distance from the line C W and are indicated by F3 and B3. All the points marked F F1 F2 F3 indicate the different positions of the forward or go ahead eccentric, and those marked B B1 B2 B3 indicate the positions of the backup eccentric.

LINK TEMPLET.

We will now proceed to make a link templet, which we will need later on. Fig. 5 shows a link, the line J being the correct

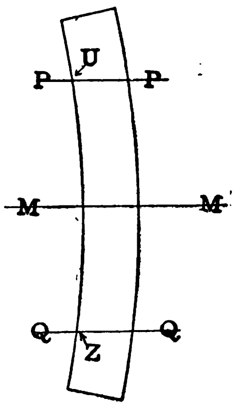


Fig. 6

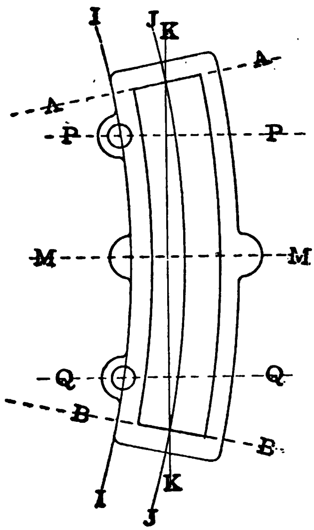


Fig. 5

radius of the link, and passing through its center. The line I being the link pin arc, and drawn from the same point as the radius. The lines P and Q should be parallel with the center line M, and all three marked on the templet. The center of the saddle pin will be located on line M, and very close, if not exactly on the line K (as already explained in Shop Practice). Now cut out all the space between the four lines A B I J and we have our templet as shown in Fig. 6. The points marked U and Z indicate the center of the link pin holes.

TO FIND THE CORRECT LENGTH OF ECCENTRIC RODS.

Make the center line of motion and the perpendicular line R S the same as before. Now locate the position of your eccentrics in full stroke when the crank pin is at G and H as previously explained. Now locate your rocker arm the right distance from the center of the axle, as shown in Fig. 7 by the letters N O and parallel to the line R S. Now find the exact distance from the point C to P, and from this length subtract the distance from the link pin arc to the radius, as shown by Fig. 5; and the remainder will be equal to the length from the center of the eccentric strap to the center of the link pin hole in the blade. Now with a radius equal to this length and from the point F, describe the arc F above the center line of motion. Now if the link was raised or lowered this arc F would indicate the path through which the link pin would travel, and what is true of this one arc is also true of all that we may hereafter make. Now from the point F1 describe the arc F1 and from B describe the arc B below the center line of motion, likewise from B1 describe the arc B1. Now place the templet on the drawing and keep the center M on the center line of motion and let the two points marked U Z on the templet just touch the two link arcs F and B. Now mark shape of templet on the drawing which indicates the position of the link, when the crank pin is on the forward center, at the point marked G. Now slip the templet back until the two points marked U Z just touch the link arcs marked F1 and B1, keeping the line M on the center line of motion. Now mark the shape of the templet on the drawing again, which indicates the position of the link when the crank pin is at H. The forward face of the link templet marked J in Fig. 5 indicates the center, or radius of the link, therefore each front face of our templet should be an equal distance from the center of the bottom rocker arm, marked P. Now by describing a small circle from the point P and tangent to the face of the forward templet, we find the back templet falls a little short of the circle. This is caused by the eccentric blades being crossed

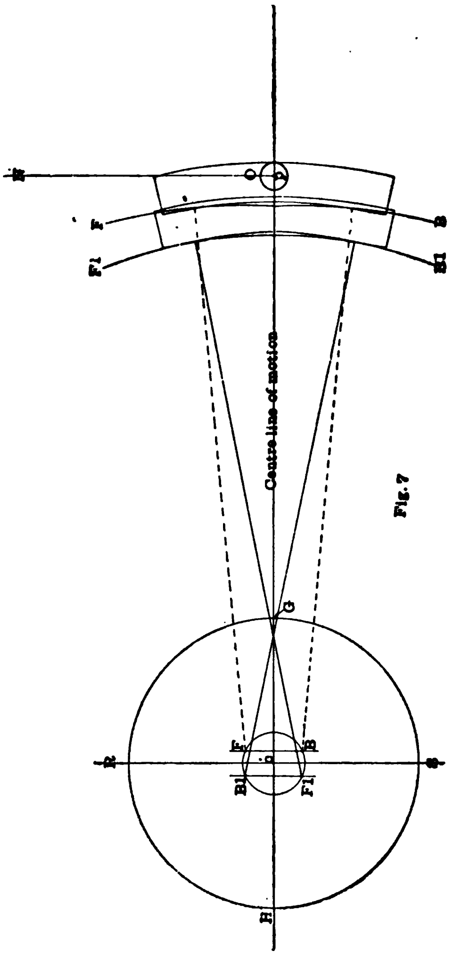


Fig. 7

when the pin is on the back center, while they are not crossed when the pin is on the forward center; we must therefore lengthen our blades one-half the amount of the distance from our small circle to the front face of the back templet, as shown in Fig. 7. This will be the correct length of the blades and they will then divide equal with the rocker.

TO FIND THE CORRECT POINT OF SUSPENSION OR POSITION OF CENTER OF SADDLE PIN.

The periods of admission and cut off may be equalized most by changing the point of suspension of the link, either up or down, or horizontally. A somewhat better distribution of steam can be secured by suspending the link above its center, but in locomotive construction there are practical objections to raising it. We have already explained that the center of the saddle pin would be located on the line M, Fig. 5; and we will now determine its exact distance from the front face of our templet, which is the link radius. Having already found the inequality in the motion of the piston to be greatest when the crank pin was at half stroke, and the crank pin and the eccentrics being rigid, it therefore becomes necessary to locate a position for the saddle pin, so that equal portions of steam will be admitted alternately, and the cut off be equal when the crank pin is at half stroke. Therefore make your center line of motion and locate the positions of your eccentrics when the crank pin is at half stroke T W as previously explained, and shown in Fig. 8. Now locate your rocker arm N O, and from the center of the rocker arm L describe the arc R S now with the correct length of your eccentric rods, and from their respective points as explained in Fig. 7 describe the four link pin arcs F F1 B B1. The forward arcs above the center line of motion and back motion arcs below it. Now when the rocker arm stands in a vertical position the valve stands central on the valve seat, and we know the valve has ⅞″ outside lap (as previously explained), therefore the bottom of the rocker arm must move ⅞″ each way from its central position to open the valve, or reach each point of cut-off (presuming rocker arms are equal lengths); therefore from the point P, which indicates the center of the hole in the lower rocker arm, mark off the two points V and V1 on the arc R S, which represents the path through which the center of the lower rocker arm must travel. Now place the point U of the templet on the arc F2 and the point Z on the arc B2 then move the templet along those lines until its front face J, Fig. 5, touches the point marked V. The templet now represents the position of the

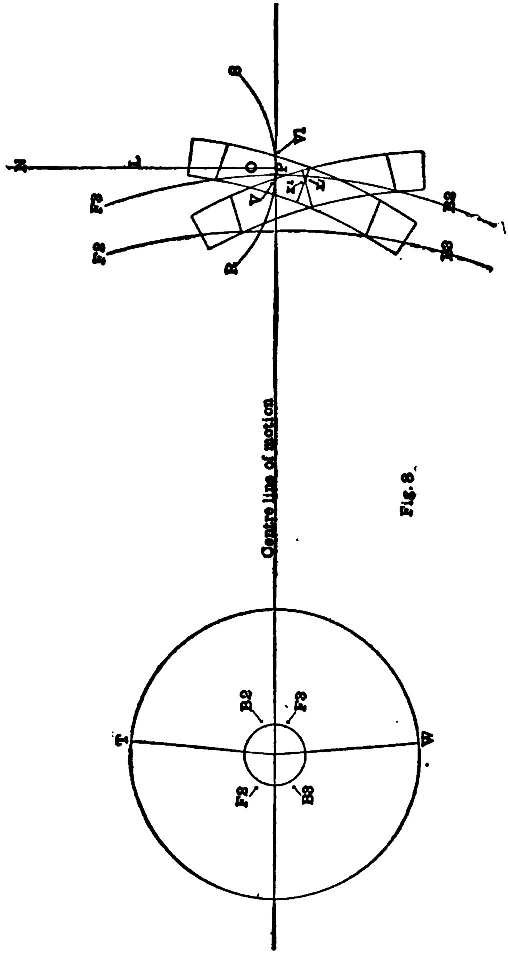


Fig. 8

link when the crank pin is at T, and we know when the engine is moving forward the valve must be cutting off steam at the back port when the crank pin has reached this position. Now transfer the line M of your templet onto the drawing for future use. Again place the point U of the templet on the arc F3 and the point Z on the arc B3 and move the templet along those lines until its front face touches the point V1. The templet now represents the position of the link when the crank pin is at W, and we know when in the forward motion the valve must be cutting off steam at the forward port at this point, so once more transfer the line M of the templet onto the drawing. Now with a length equal to the distance between the lines J and K and on the line M, Fig. 5. From the forward face of each templet and on the line M lay off the two points X1 X2. If a straight line drawn through these two points is parallel with the center line of motion they indicate the correct position of the center of the saddle pin. If not then by trial locate two points an equal distance from the front faces of the templets that are parallel to the line of motion, which will be the correct position of the saddle pin. For future use, when the correct position is found, mark it on the templet.

RELATIVE POSITION OF THE TUMBLING SHAFT AND ROCKER, AND LENGTH OF THE TUMBLING SHAFT ARMS.

The saddle pin is usually located in a position to obtain an equal cut off at half stroke, where the irregularities introduced by the crank pin are greatest and the tumbling (or lifting) shaft is located in a position to obtain an equal amount of lead in full stroke. Owing to the irregularities of crank motion it is impossible to obtain an equal lead, and an equal cut-off at all points: If one is equal then the other will not be; this is one of the imperfections of link motion, but the difference is so slight in full gear that the cut-off is considered of less importance than an equal amount of lead at the beginning of each stroke, therefore the tumbling shaft is located and the length of its arms determined to obtain the latter result. In making Fig. 9 we must combine all the foregoing problems. Make the center line of motion, locate the eccentrics at full and half stroke, locate the rocker arm N O and from its center L describe the arc R S. Now from the position of each eccentric and with the correct length of the eccentric rods, describe each link pin arc as shown in Fig. 9; make all the forward motion arcs above the center line of motion and all the back motion arcs below it. Now locate the points X1 and X2 as

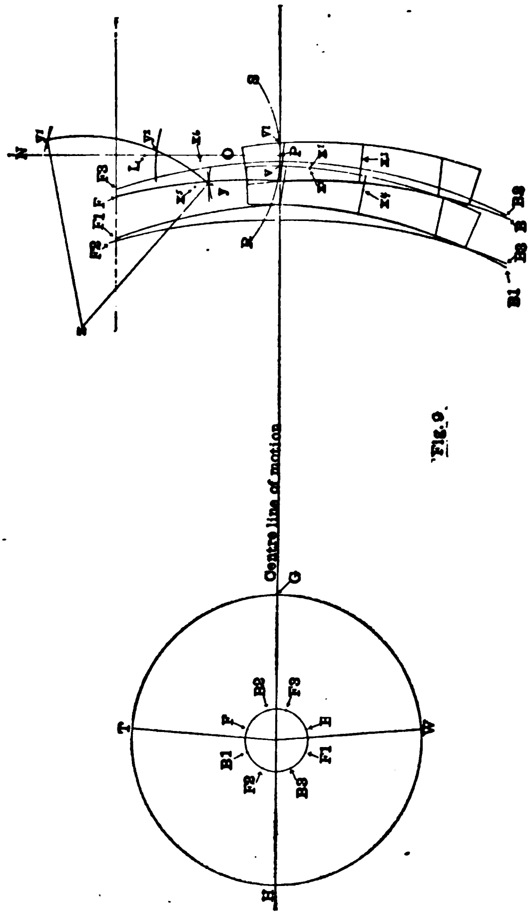


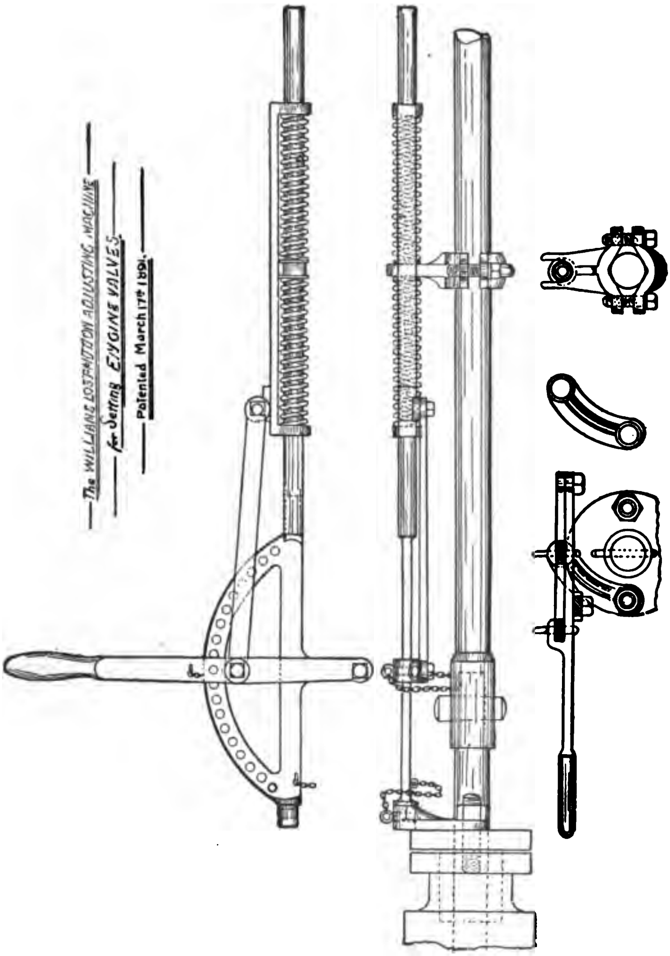
Fig. 9.

explained in Fig. 8, which indicates the points of suspension when steam is cut off equal at half stroke. Mark these two points on your drawing Fig. 9. Now to determine the length of the tumbling shaft arms and the position of the tumbling shaft, we must find the points of suspension in full forward, and full backward strokes at each end of the cylinder. The valve has ⅞″ outside lap and 1-16″ lead, therefore add the amounts together and locate the points V and V1 on the arc R S and 15-16″ from the point marked P. Now place the templet on the drawing with the line M below the center line of motion, place the point of templet marked U on the arc F and the point marked Z on the arc B, and move it along these lines until its front face touches the point V1, and then mark the point X3 on the drawing; this point will indicate the position of the saddle pin when the crank pin is at G in full gear, forward motion. Again place the templet on the drawing with the line M below the center line of motion, place the point U on the arc F1 and Z on the arc B1 and move the templet until its front face touches the point V; now mark the point X4 on the drawing. This point indicates the position of the saddle pin when the crank pin is at H in full gear forward motion. Now we must find the points X5 and X6 in exactly the same manner, and using the same link arcs as before, only that the line M of the templet must be above the center line of motion. We have not outlined the templet in these positions as it would make the drawing appear more complex, but we shall continue the explanation. Place the point U on the arc F and Z on the arc B, front face of the templet touching the point V1. Now mark the point X6. Again place the point U on the arc F1 and Z on the arc B1, letting the front face of the templet touch the point V. Then mark the point X5 on the drawing. These two points indicate the position of the saddle pin when the piston is at each end of the cylinder, in full gear, backward motion. Now from the two points X3 X4, with a radius equal to the length of the link hanger, find the point marked Y, and from the points X5 X6, with same radius, find the point Y1, and from the points X1 X2, with same radius find the point Y2; now from these three points Y Y1 Y2 find the point Z on the drawing which indicates the position of the center of the tumbling shaft and the distance from the point Z to either of the three points Y Y1 Y2 equals the length of the tumbling shaft arms. The length of the top arm of the tumbling shaft is not so particular, as it is made to suit other details of the engine.

Valve Setting.

LOST MOTION ADJUSTING MACHINE.

The purpose of the device illustrated herewith is to facilitate the work of setting locomotive slide valves, by putting the valve gear under a certain amount of strain, so as to prevent lost motion or back lash, and to insure more accurate setting of the valves than if they are under no strain as is usually the case in this work. An arm is attached to the outer stud of the valve stem gland and a clamp is bolted to the valve rod; these attachments are of malleable iron and are placed on both sides of the engine, and the malleable iron sector and the ⅞″ steel rod on which the two steel springs are placed are supported by these attachments on which ever side of the engine the valves are being adjusted. The springs are of No. 6 steel wire with two coils to the inch and so tempered that if compressed solid they will return to their original length. The springs bear against the upper part of the clamp and are compressed by a sliding bar with sleeve ends fitting over the ⅞″ rod, the bar being moved by the hand lever and connecting bar. The lever connecting bar and slide bar are of malleable iron. The clamp is so set on the valve rod as to be 26½″ from the arm when the valve is on the middle of its seat. The methods of operation are as follows: Supposing the crank to be 6″ behind the back dead center and the reversing lever in full gear ahead, the lever is thrown far enough toward the cross head to get a good strain against the clamp and is then secured in position by a pin through the sector. The crank is then put on dead center and the valve rod marked with the tram; then the crank is put 6″ ahead of the center and then back to the dead center with reverse lever in full back gear, the valve rod then moving against the strain of the spring, the same operations are gone through for the forward dead center, the lever then being thrown toward the other end of the sector; the object being to compress the spring in the opposite direction from which the valve rod is moving, but the spring should never be compressed solid. In setting eccentrics the spring is first compressed against the clamp so as to offer resistance as the eccentric is being turned to give the necessary lead of the valve.


The WILLIAMS LOST MOTION ADJUSTING MACHINE
for Setting ENGINE VALVES
Patented March 17th 1891.

IMPROVEMENTS.

In the Wabash shops at Springfield, Ill., a small engine that is run with air is attached to the rollers for valve setting. It performs good work rapidly, and it is claimed that it can "catch" a center every time.

ROLLERS DRIVEN BY ROPE PULLEYS.

Another device for turning the rollers when setting valves consists of worm wheels placed on each roller shaft, driven by other worms which are attached to a square shaft. At the end of the square shaft which connects the two worm wheels is placed a small lever with reversing gears. It is claimed the driving wheels may be brought within 1-16″ of the center and stopped, and then by placing a monkey wrench on the square shaft and giving a slight turn the wheel may be brought to the exact center. This device is in use at the A. V. Ry. shops at Verna, Pa.

HOW TO SET A LOCOMOTIVE'S VALVES.

Introduction.

We must presume the reader has had considerable experience at his trade, and is familiar with the mechanical terms which must be used in explaining this work, such as dead center, port marks, etc. He should thoroughly understand what the port openings are and how to get them, and study all our rules for valve setting. He should also know how to disconnect parallel rods and place rollers under main wheels; but as there are yet many shops where the pinch bar is still used, for convenience in our explanation, and in order that all may understand, we will use the word "pinch."

Some men move the engine with steam when squaring the blades, then get one dead center on each wheel and try both eccentrics to it, but we will not. Others chalk down lead and lap on the guides, but that is unnecessary, so we will not.

PREPARATION.

See that you have a valve tram, cross head tram, wheel tram, and eccentric tram; also dividers, hermaphrodites, and small center punch. Examine port marks on your valve stem, and know that they are correct with your valve tram; if in doubt raise both steam chest covers and make new marks.

See that valve stem keys, main rod keys, main wedges, eccentric set screws and blade bolts are all tight, and that reverse lever latch will enter each extreme notch in quadrant. Now you are ready to begin.

HOW TO GET A DEAD CENTER.

You may begin at any point where the main crank pin is approaching either dead center while in forward motion. (A pin is on dead center when parallel with wheel centers.) But for convenience we will begin at R forward center. Pinch forward until R crank pin is about 6″ above dead center, then stop. Put a small center in right front guide block, or front end of guide; use cross head tram in it and scribe a line on cross head. Now put another center in wheel cover, or on frame; use wheel tram and scribe a line on tire of wheel.

Now pinch forward until crank pin passes dead center and catch same line on cross head with cross head tram, as it leaves dead center, (See rule 20.) then stop. Now use wheel tram again in same center and scribe another line on tire. Now use hermaphrodites from inside of tire if possible; if not, then from outside, and scribe a line through both lines made with wheel tram. Use dividers now and find the center between the two lines made with wheel tram. This center is your dead center, so circle it with dividers, or chalk, so as not to get it mixed up with other centers.

HOW TO TRY THE LEAD.

Place reverse lever latch in back notch of quadrant (See rule 10) and pinch backward until you catch the dead center with your wheel tram; then stop.

Now use valve tram and mark valve stem with it below parallel line on stem. (See rule 2.)

Now your engine is on dead center, so scribe a line on guides at front end of cross head, which designates extreme travel of cross head. (See rule 9.)

Now place reverse lever in forward notch in quadrant, and pinch backward (See rule 10) until valve stem moves, which indicates that all lost motion is taken up; it usually requires the wheel to travel from 2 to 6 inches. Now pinch forward and catch dead center with wheel tram. Now mark valve stem again, this time above parallel line. (See rule 2.)

Now you have finished with one dead center; there are four in all, two on each side, one forward and one back, and they must each be got in exactly the same way, only on each back center; use cross head tram from back guide block, and

the valve stem must be marked exactly the same way on all four dead centers.

After finishing with right front dead center, go to left side of engine and get left front dead center. When you have finished with it return to the right side and get right back one; then return to left side and get left back one.

Then you are done pinching for the present; you have the engine run over once, and we will now see what changes are necessary to be made.

HOW TO MAKE ALTERATIONS.

First—Measure the length of inside and outside arms of your rocker; if they are equal lengths then we know we must move the eccentric blades exactly what the valve stem calls for. But if the inside arm is the shortest, which is frequently the case, then we will not have to move the blades quite so much. (For example, if top arm is 12″ long and bottom arm only 9″, and the valve stem calls for ⅛″, then you see by moving the blade 3-32″ the valve stem would move ⅛″, and different lengths in proportion.) But in this case we will presume both arms are of equal lengths.

Now we will presume all the marks you have made on the valve stem correspond with the figures we shall use in explaining this work, and that you wish to give the engine 3-32″ lead all around. (See rule 11.)

The cut on page 93 shows our port marks and tram marks.

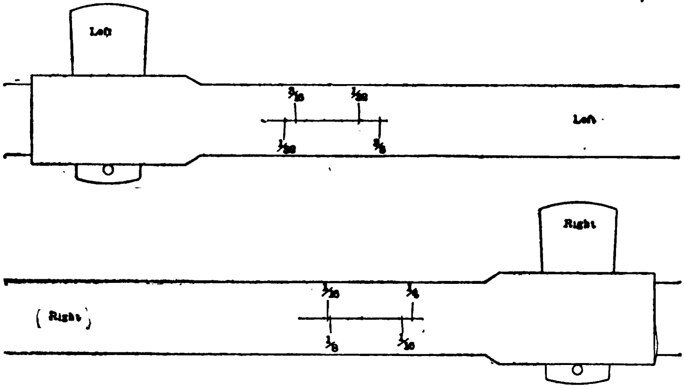
Now we will take both forward motion marks on right side. We find it shows ¼″ lead on front center and 1-16″ lap on back center (See rule 3); therefore shorten blade 5-32″. (See rule 12.)

Mark R F blade with chalk thus, shorten 5-32″, but make no changes until you mark all blades; then change all blades at the same time. Now figure on how your marks will come after that change is made. When you shorten the blade you know it moves the valve stem forward, and vice versa. So take 5-32″ off the ¼″ lead, which will leave 3-32″ lead, and add 5-32″ onto 1-16″ lap, which will make 3-32″ lead. Now you will have 3-32″ lead at both points, which is what you want. Therefore your R F eccentric is right.

Now take both back motion marks on right side; it shows 1-16″ lead in front and ⅛″ lap behind. By observing Rules No. 3 and 12 carefully you will find that we must shorten R B blade 3-32″, which will leave 1-32″ lap on both ends. Therefore give the R. B. eccentric ⅛″ lead. (See Rule 1.)

Now try both L. F. marks and you find that you must lengthen blade 5-64″, which will leave 3-64″ lead at each point; therefore give L. F. eccentric 3-64″ more lead. (See Rules 1

and 12.) Now try two L. B. marks and you find you must lengthen blade 11-64″, which will leave 13-64″ lead on both



points; therefore take off 7-64″ lead from L. B. eccentric. (See Rules 1 and 12.)

Now make all these changes and you are ready to try the cut-off. Some men run the engine over twice before trying cut-off, but we will not.

TRYING THE CUT-OFF.

A locomotive performs most of its work with the reverse lever hooked up near center notch, therefore it is more essential to have an engine "square" in the cut-off, or where hooked up, than in the corner notch.

If link motion was a perfect valve gear it would be unnecessary to try the cut-off, for if square in the corner notches it would necessarily be square in every notch; but link motion is not a perfect valve gear, owing to the angularity of the rods, and the variation in the speed of the piston, and also of the valve stem. Off-setting the link saddle pin only approximately corrects the inherent error of the link motion. The reader knows the piston travels faster at some points than at others, and also the valve stem. You will also notice that when the crank pin is on the top quarter, the cross head has passed the center of travel on the guides.

You should try the cut-off on a passenger engine at about

6″, and a freight at about 9″. We will presume this is a passenger engine.

Pinch engine forward until R. M. pin passes forward dead center. Measure cross head as it leaves travel mark on front end of R. guides, and when it is 6″ from your travel mark, then stop.

Throw reverse lever clear ahead, then haul it back slowly until your valve tram is right with your R. F. port marks; then stop and hook lever there. Now pinch back until valve stem moves, which will take up all lost motion. Now pinch forward until valve tram is right with R. F. port mark, then stop and measure distance from cross head to front travel mark; we presume it shows 5¾″, so chalk that down on front end of R. guide.

Now go to left side (leave reverse lever in same notch until you finish); pinch forward until crank pin passes forward center and catch L. F. port mark with your valve tram; then stop and measure distance between cross head and L. F. travel mark. It shows 6¼″; chalk it down on front end of L. guide.

Now return to right side; pinch forward and catch back port mark after crank pin passes back center. Measure distance between cross head and back travel mark, and chalk down on back end of R. guide, 5¼″.

Return to left side, pinch forward and catch back port mark after pin passes back center. Measure distance between back end cross-head and back travel. Chalk it down on back end of left guide, 6½″. Now you have finished pinching.

CHANGES TO MAKE IN CUT-OFF.

On the right side we will find the engine cuts off quicker behind than it does in front. The difference we find is ½″. (This is caused by the wear of the link and block or the imperfect construction of the valve gear. If engine is out very bad, see Rules 17 and 21.) Therefore shorten R. F. blade 1-32″. On left side we find engine cuts off quicker in front, ¼″ difference; therefore lengthen your L. F. blade 1-64″. Now see which side carries or holds its steam the longest. To do this, add the cut-off at both ends on R. side, which amounts to 11″. Now add left side, which amounts to 12¾″. Now we find she carries her steam longest on the left side, the difference being 1¾″; therefore one link must be raised or the other one lowered, so they will each cut-off the same. There are many ways to do this. (See Rule 17.) Put ⅛″ liner under tumbling shaft stand on left side. (See Rule 18.) Remember when you place liner under tumbling shaft stand you raise both links—one about 1-3 as much as the other—and when you

line under a rocker box the other side is not affected; therefore 1 16″ under a rocker will amount to as much as 3-32″ under the tumbling shaft stand.

Now in order to try the exhaust opening and closure we must find additional points on the valve stems. If the valve is line and line inside then you know the point of opening and closure will be indicated by the dead center between the port marks, but if the valve has inside lap it will be quite different, as the valve will cut off the exhaust before it has reached its central position, while it will not release until it has passed its central position. While if the valve had inside clearance these conditions would be reversed. So it will be well for a novice to distinguish these points by private marks or letters when found.

To find these points use a pair of small dividers and from the dead center between the port marks and with a radius equal to inside lap or inside clearance, as the case may be, describe a small circle on each valve stem and make two centers where the circle crosses the horizontal line, and mark each whatever it represents, as previously explained. Now remember the opening when the valve is in one motion will be the closure when in the other motion, and vice versa.

Now when you have these marks, proceed to try each by measuring the cross-head as you did the cut-off, and mark down each point. Now compare these figures; alterations may be affected same as in the cut-off; but remember compression is of more importance than release, and compression and lead opening should be made as near perfect as possible. Indicator diagrams will expose these defects much clearer than they could be explained here.

RULES FOR SETTING VALVES ON LOCOMOTIVES.

RULE 1.

On all standard engines with indirect motion, to increase the lead, move the rib (or belly) of eccentric toward the crank pin.

To decrease the lead, move away from pin. On all engines with direct motion, move the eccentric just the reverse from standard engine.

Mark eccentric and shaft with a "V" chisel or three-pointed tram, and move exact amount valve stem calls for, providing rocker arms are of equal length.

RULE 2.

Always mark forward motion above parallel line on valve stem and back up below.

RULE 3.

If tram marks come between port marks, it indicates so much lap (sometimes called blind); if outside, so much lead. This is the rule. But occasionally when blades and eccentrics are out bad, a tram mark may lap outside of opposite port mark and appear as lead. Always notice which center your pin is on and which port mark you are trying.

RULE 4.

When crank pin is on forward center, always figure your valve tram marks from front port mark; when on back center, from back port mark.

RULE 5.

The distance between the port marks always indicates the amount of outside lap; the valve has one-half that amount on each side of valve.

RULE 6.

With standard type of rocker arm, the forward (or go-ahead) eccentric should always follow the crank pin, when engine moves forward, and the back-up eccentric should lead pin when engine moves forward. On some engines both arms of the rocker extend upward; in this case you have direct motion. Therefore go-ahead eccentric should lead crank pin, and back-up eccentric follow crank pin going ahead.

RULE 7.

Due care should be taken when connecting eccentric blades to the link. Remember on all standard engines the forward motion blade should be attached to the top of the link and the back motion to the bottom of the link. The position of the eccentrics is not the same on all engines. On some the back motion eccentric is next to the box, and on others the forward motion is next to the driving box. When coupled up wrong the engine will move in the opposite direction, when

the reverse lever is placed in either motion. Through negligence good mechanics sometimes make this error.

RULE 8.

As a rule the R. crank pin is always ¼ ahead of L. crank pin while in forward motion.

RULE 9.

Always mark extreme travel of cross-head on guides while engine is on dead center, at each of the four points. Travel marks are sometimes called danger marks.

RULE 10.

When trying forward motion, always see that reverse lever is in forward notch, and have engine pinched back of dead center enough to take up all lost motion, about 6″. Then pinch forward and catch dead center; then mark valve stem. When trying back motion, place lever in back notch and pinch ahead enough to take up lost motion; pinch back and catch dead center and mark valve stem.

RULE 11.

For our explanation of valve setting, we will give the engine 3-32″ lead all around in full gear, this amount perhaps exceeding the average. It is impossible to lay down any definite rule as to the proper amount of lead that should be given. The amount which would give the best results on one engine might not do so on another, owing to the difference in the design of different locomotives, the best practical amount for each engine being ascertained by the use of the Indicator. The volume of the clearance space, the cut-off, and other causes influencing the amount of lead given, which varies from ⅛″ to 1-64″, while on some of the latest engines built, the lead in full gear is zero. Advocates of early admissions claim that the cylinder and piston have become cooled during exhaust and should be reheated as early in the stroke as practicable, while the argument in favor of a late admission is, that while the crank is at or near the dead center, pressure against the piston will have no effect to turn the shaft, but rather preventing its turning by increasing the friction on the pins and main shaft. There is reason in both arguments. We do not think there is much loss or gain by either early or late admissions, within practical limits, and would

advise that the lead be such as will produce the best results otherwise. There is a growing tendency among the locomotive builders of the present day to reduce the lead from 1-10″ to 1-32″, while some of them give only 1-64″ in full gear, as may be seen by referring to the dimensions of the several locomotives herewith illustrated. (See Rule 24). For explanation why an engine is given lead, see "The Slide Valve," p. 17.

RULE 12.

To find out whether to lengthen or shorten a blade, use small dividers and get centers between your two forward motion tram marks, or your two back motion tram marks. If the center is ahead of the center of port marks, shorten blade the exact amount of the difference between the two centers. (This implies rocker arms of same lengths). If the center is back of the center of port marks, lengthen; if arms are different lengths, move blades in proportion

RULE 13.

When setting eccentrics on shaft temporarily, place rib of eccentric about parallel with third spoke from crank pin.

RULE 14.

Should your engine show 3″ or 4″ heavier, that is, carry her steam that much farther, on one side than on the other, there is something wrong. Examine arms on your tumbling shaft and see if either arm is sprung or bent, up or down.

RULE 15.

Keep all your eccentrics exactly same throw.

RULE 16.

Steam ports should all be kept exactly the same size. A variation in size will make one exhaust heavier than the other, and sometimes break crank pins.

RULE 17.

Before making any alterations to benefit the cut-off, go at it in a mechanical way and locate the part that is not right. See if your link hangers are of an exact length. Place a

straightedge across the frames and level it by the cylinders, and see if the centers in the two arms of your tumbling shaft are exactly the same distance to straightedge. Then try the centers in your rocker boxes with straightedge, and make any change that will raise the link, or lower the link block, on the heavy side of your engine; or lower the link or raise the block, on the light side of engine. (Heavy side is the side that carries its steam the longest.) Should your engine cut off 3″ or 4″ heavier in front or behind, you must locate the cause at once. It may be the rocker arm may have too much or not enough back-set. Try that; then try the off-set of your link saddle and see if reach rod is right length by trying the cut-off in both extreme notches. See if each eccentric has same throw. If any part is right, do not alter it.

RULE 18.

Lining a link 1-16″ up or down will usually make 1″ difference in the cut-off.

RULE 19.

When trying the length of your reach rod, by trying the cut-off in each extreme notch of quadrant, remember most engines carry their steam 21″ in forward motion and 20″ in back motion.

RULE 20.

When finding the forward dead centers on the main wheel, you will notice the main rod is pushing the cross-head when approaching the center, and pulling it after it passes the dead center, and back centers just the opposite. So you see, if there was any lost motion in your main rod, your dead center would not be correct. Therefore, to overcome this error, after you have marked a line on the cross-head when approaching the dead center, pinch past the center and past your line; then back up again and catch your line. Then the strain on the cross-head will be the same each way from dead center. This rule should be strictly observed on all engines with much lost motion. Otherwise your dead center on the wheel might be out 2″ or more.

RULE 21.

When your engine does not cut off equal front and back, and you have located the cause to be in the link saddle, use an adjustable link saddle, if you have any; if not, use temporary bolts in your saddle, and adjust saddle forward or back as may be needed until engine cuts off equal.

RULE 22.

Remember if your valves have no inside lap, or inside clearance, one exhaust opens and the other closes, just as the valve moves either way off the center between your port marks. While if the valves have inside lap, or inside clearance, the point of release and compression will take place earlier, or later, according to the amount.

RULE 23.

When the valve is given an equal amount of lead in the forward and back motion the eccentrics are not always an equal distance from the crank pin, as so many men believe (even if the cut-off be equal in each extreme notch.) Remember the eccentrics are set from the center line of motion and not from the crank pin, so the bottom arm of the rocker will travel an equal distance each way (see Technical Points, page 77.) This is a technical point, but as the eccentric blades are so long and the line of motion usually so close to the pin when it is on center, that for all practical purposes, set your eccentric by the pin when setting them temporarily.

RULE 24.

Remember lost motion in the valve gear decreases, and often nullifies the amount of lead given the engine in full gear. Therefore it is important that all lost motion should be taken up when setting the valves, otherwise an old engine may be running blind in full gear, and yet, with a valve tram apparently have the required amount of lead. This evil would be clearly shown on an Indicator diagram. (See Rules 26 and 35.)

RULE 25.

The angular advance of an eccentric means the distance the center of the eccentric is advanced toward the pin from a line through the center of the axle, perpendicular to the line of motion. (See Technical Points.)

RULE 26.

Lead increases as the reverse lever is drawn toward the center notch in proportion to the radius of the link. This increased lead is sometimes injurious to slow, hard pulling engines. To remedy this evil the angular advance of the back-up eccentric is decreased, in order to benefit the forward gear.

Many freight engines of this kind are in use on the Pennsylvania railroad that are run ⅜″ blind in back gear. Decreasing the angular advance of one eccentric gives the other motion almost a constant, unvarying amount of lead between full gear and the center notch.

RULE 27.

Remember a perfect equalization of admission and cut-off for both gears is practically impossible with link motion. If the lead is perfect the cut-off will not be, and vice versa. Equalization of the back gear is usually sacrificed to benefit the forward gear. This is the inherent imperfection of link motion, but it can be made almost perfect.

RULE 28.

When eccentrics are worn out of round very bad, remember you can reduce the size of one or all of them by turning them up, without affecting the valve motion. Provided you do not change the throw. Of course the eccentric blade will have to be lengthened so as to divide equal.

RULE 29.

By "dead center" is meant when crank pin is parallel with wheel centers. By "the quarter" is meant when pin is at right angle with dead center, either on top or bottom; and by "eighth" is meant when pin is half way between dead center and quarter.

RULE 30.

If you have a "hurry-up job," change all blades, but try engine in cut-off before you change any of her eccentrics. You can figure this way: If you put on ⅛″ lead on an eccentric she will carry her steam about ½″ less at both front and back points. That will make a difference of 1″ in cut on that side; and if you take off lead it will cut off that much later.

RULE 31.

If you have a right and left nut on your valve stem, remember if both your blades on same side need lengthening ⅛″, you can shorten valve stem ⅛″ and save changing blades (providing rocker arms are the same length;) or if blades need shortening you can lengthen valve stem; but if you know your valve stem is the right length do not change it.

RULE 32.

If your main rods need alteration, figure on it when figuring on your change for cut-off.

RULE 33.

Remember you can change the lead on an engine by changing length of reach rod or link hangers, but what you put on the two go-aheads you take off the back-ups, or vice versa.

RULE 34.

Remember if one eccentric blade is not the right length it will affect the other motion and cause the valves to sound "out." The effect will be greatest when the reverse lever is hooked up, but it will be scarcely perceptible in full gear.

RULE 35.

Allen valves with the double opening should be given the same amount of lead as the plain slide valve. The reason for this is that it will maintain the initial pressure better at early cut-offs than the plain slide valve, and the pressure will be more uniform during the period of admission, on account of the double opening.

RULE 36.

When the exhaust is perfect, steam is not always perfectly equalized, and it is sometimes necessary to sacrifice a perfect exhaust to a correct equalization of steam. For example, if one cylinder was considerably larger than the other on a single expansion engine, the large cylinder should be given an earlier cut-off, or the small cylinder a later cut-off in order to equalize the volume of steam admitted to each cylinder. Such an inequality would be readily discovered by the use of an Indicator.

RULE 37.

By referring to Technical Points we find that it is impossible to secure a perfect equalization of steam in both gears with the shifting link motion. If the lead is equal, the cut-off will not be, and vice versa. This is due to the angularity of the connecting rods. By advancing the exhaust on the back edge of the valve in proportion to the clearance the compression

may be equalized in both ends of the cylinder and the exhaust will sound perfect. This is done on some of our modern engines. Those familiar with the Indicator diagrams will readily perceive the advantage.

RULE 38.

When the rocker arms are of equal length, the travel of the valve in mid-gear equals twice the angular advance plus the increase of lead in mid-gear.

General Information Regarding Valve Setting.

In some shops, when the valves are set perfectly square and finished, they shorten each of the four blades 1-64″ (providing the engine is new or has received a general overhauling), so when the engine settles, and wedges are tightened up, she will be perfectly square, for the settling of the engine and setting up of her main wedges always lengthens all four blades.

In many shops, when an engine is cold, they always give each back-up eccentric 1-32″ more lead than the go-ahead. This allows for expansion of boiler, for the quadrant is usually attached to the boiler, and as the boiler expands from ¼″ to 5-16″ when hot, it takes quadrant back too, and therefore raises the links, and by raising the links you increase the lead on the two go-ahead eccentrics, and take lead off the two back-ups.

You will learn from experience that when an engine has 3-32″ lead in the corner notch it has 5-16″ or ⅜″ lead when hooked up on center. This is caused by the radius of the link.

When the link is stationary, and the link block raises and lowers in the link, the lead does not increase. On some engines the link and block both move, having four arms on the tumbling shaft instead of two. The two longest arms, in front, adjust the block, while the two short arms, behind, move the link slightly. (A sample of these engines may be seen on the P., Ft. W. & C. Ry.)

The "Bogie" engines, which have the Walschaert valve gear, have no eccentrics, but have a crank fastened onto the outside of each main crank pin, and one stationary link on each

side fastened outside of the guides, with the tumbling shaft on top of the boiler, have indirect motion in the forward gear and direct motion when placed in the back gear. In this case the crank follows the pin while in the forward motion, and leads the pin in the back motion, thereby doing the work of two eccentrics. The lead does not increase upon these engines, and they are usually given ¼″ lead. Very few of these engines are now in use. (Some of them may be seen upon the T., St. L. & K. C. Ry.)

A yoke and block at the top of the rocker arm is used upon many locomotives, as it dispenses with the circular movement imparted to the valve by the up and down motion of the rocker, and prevents wearing the valve seat hollow.

A RADICAL CHANGE IN THE SLIDE VALVE.

It will no doubt be surprising to many of our readers to know that several of the large roads in this country give their passenger engines from 1-16″ to ¼″ inside clearance, according to the valve gear, and some of them have used so much as 5-16″ inside clearance (on each side.) But that amount proved wasteful on steam; 3-16″ on each side is the amount mostly used. This is the result of many experiments upon the testing plant. Economy is claimed for inside clearance, as it makes the engine smarter by giving an earlier release.

A MODERN METHOD OF VALVE SETTING.

After many experiments upon a testing plant, one of our largest roads have adopted the following method of valve setting: Instead of giving their engine a certain amount of lead in full gear, as most roads do, they give 3-16″ lead with the reverse lever in the fourth notch (or wherever the engine performs most of its work.) This method shows but a slight variation upon the valve stem, from the old way, as the reader knows the lead increases as the reverse lever is moved toward the center notch of the quadrant. With the lever in the center notch the lead will vary from ¼″ to ⅜″, owing to the radius of the link. But a slight variation in the lead often makes a vast difference in the results, when figured by units of work performed; per pound of coal consumed per horse power per hour. For the benefit of our readers we have reproduced on next page the most systematic form for valve setting that has been brought to our notice.

FORMULA FOR VALVE SETTING.

Valve Motion of Engine No.______Class______out of______________Shops.

______________________________*189*___

Cylinders ______________ x __________
Steam Ports______________ x __________
Exhaust Port______________ x __________
Bridges__________________________
Outside Lap________________________
Inside Clearance_____________________

Throw of Eccentric____________________
Travel of Valve_______________________
Saddle Pin Back______________________
Lead Full Gear_______________________
Valves Set by________________________

	REVERSE LEVER MOTION.	CUT OFF FRONT END.	CUT OFF BACK END.	DIFFERENCE IN CUT OFF.	EXHAUST OPEN, FRONT.	EXHAUST OPEN, BACK.	DIFFERENCE IN EXHAUST OPENING.	EXHAUST CLOSES, FRONT.	EXHAUST CLOSES, BACK.	DIFFERENCE IN EXHAUST CLOSURE.	LEAD FRONT.	LEAD BACK.	MAXIMUM PORT OPENING.
FORWARD MOTION.													
BACK MOTION.													

REMARKS: ____

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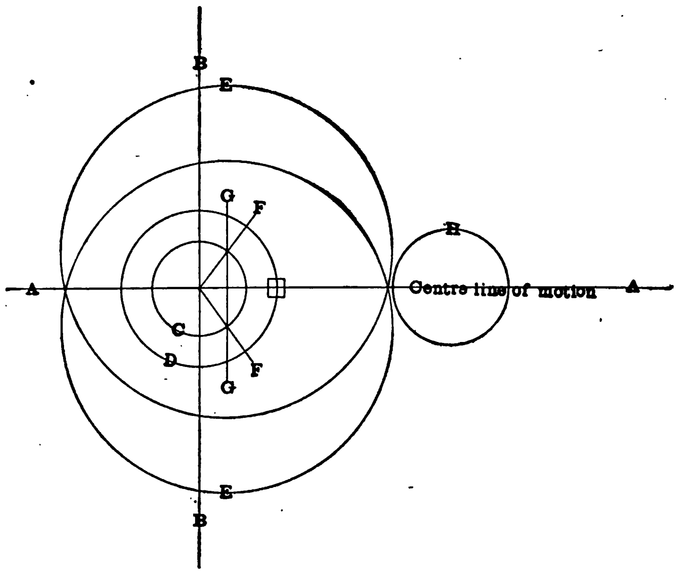
MASTER MECHANIC.

HOW TO LAY OFF KEY WAYS FOR ECCENTRICS BEFORE WHEELS ARE PUT UNDER ENGINE.

This rule may be used for any sized shaft or any throw of eccentric with standard rocker arm, providing rocker arm has no back-set, and it can be laid off on end of shaft and lines carried over (to place where eccentrics fit on the journal), with box square, or it can be laid off on face plate.

First make line A through center of crank pin and center of shaft; then make line B at right angle with line A.



Now add amount of lead required to outside lap of valve and make line G that distance from line B and parallel with it.

Now take half the throw of your eccentric and make circle C. Now put two small centers where circle C crosses line G. That indicates center of your eccentrics.

Now make lines F through center of shaft and center of eccentrics; circle D represents size of shaft. So the points

where line F crosses circle D indicate the center of your keyways.

Circle E represents outside of eccentrics, and circle H represents size of crank pin.

Reason will teach you that if the valve had no outside lap or lead, the center of your eccentrics would need be on right angle with crank pin.

In this sketch line A is the center line of motion. Remember the center of eccentrics are always set by the center line of motion (see Technical Points). If the rocker arms are of different lengths, measure how far the bottom arm will move while the top arm moves the amount of lead and lap, and make line G that distance from the center of the shaft.

HOW TO LAY OFF A NEW QUADRANT.

Place either M pin on either dead center and throw reverse lever forward until link block on that side clears top of link 1½"; fasten lever there; pinch wheel over one turn and you will find your travel about right; if not enough, throw lever further ahead; if too much, haul it back a little. When right, fasten your lever there and mark quadrant. Get back notch same way.

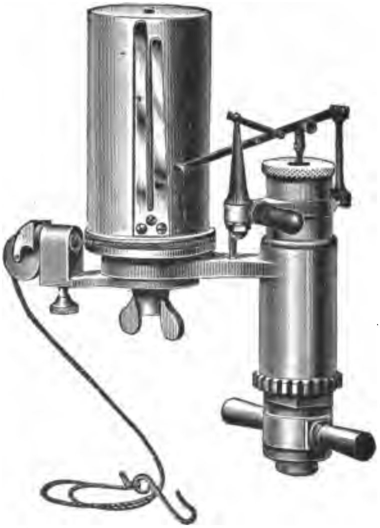
Another way to get corner notches is to square your blades first, then turn wheel forward until cross head has passed from travel mark 21" (or whatever you wish engine to cut-off at in extreme notch). Then throw reverse lever forward until valve tram is right with forward port mark, and get back notch same way, by turning wheel backward and throwing lever backward. Then proceed to set your valves in corner, but not in cut. When your blades are square, try and see if she cuts off the required amount in corner notches, before changing the eccentrics; if right, set all your eccentrics.

Place reverse lever in forward notch and pinch forward until cross head passes dead center and reaches the amount of cut-off desired for each forward notch, measuring from travel to cross head. Then haul lever toward center until you catch the proper port mark with valve tram. (If pin is leaving forward center, catch forward port mark with valve tram; if leaving back center, catch back port mark), and scribe the quadrant for each notch.

Place reverse lever in back notch and get back notches same way, by hauling reverse lever toward center. Then slot out notches in your quadrant, and you are finished.

THE STEAM INDICATOR.

The steam engine indicator is an instrument for measuring and recording pressures. Its invention, although in a crude form, is credited to James Watt. It has gradually been im-



ROBERTSON-THOMPSON INDICATOR.

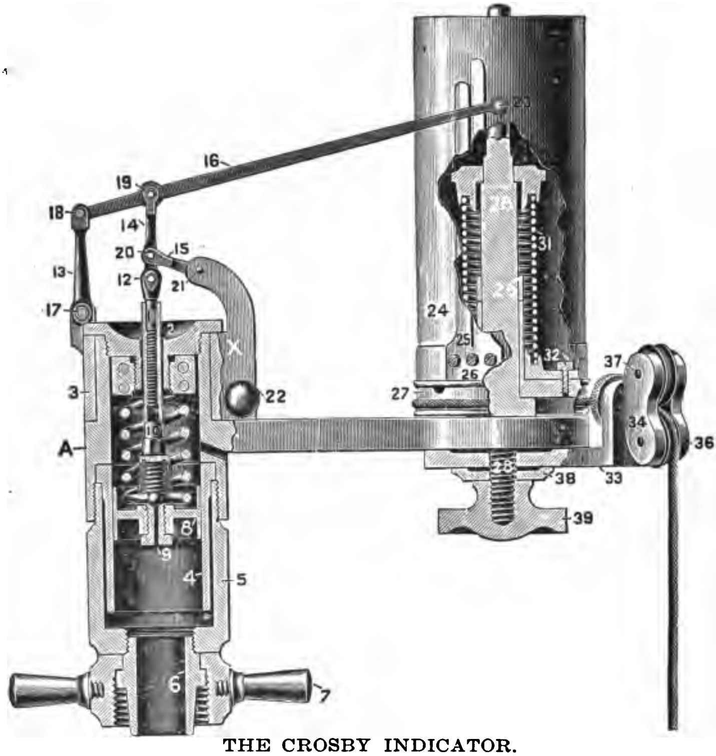
proved until in its present form it will point out the least distortion in a correct distribution of steam, thereby permitting of a correct adjustment of the valve gear. Therefore its use is considered indispensable with an economical use of steam. It is in constant use upon many of our best roads, and locomotive builders do not consider their engines finished until the valves have been adjusted with the indicator. Nevertheless at the present time comparatively few roadmen, or shopmen, understand the operations of the indicator, and yet, the indications are, that within a very brief period every first class machinist will be required to operate and adjust

the valves by its use, and every engineer will be required to know the principle upon which it operates, and be able to (at least) read its diagrams. We will briefly explain the construction and use of the indicator; definitions of the technical terms used; its method of operation and application; and give instructions for reading its diagrams (or cards). For a more complete knowledge of the subject we advise you to secure some special treatise on the indicator, of which there are many published.

CONSTRUCTION AND USE OF THE STEAM INDICATOR.

The modern indicator is a very sensitive and delicate instrument, and as near perfection as any piece of mechanism can be made, and its records are universally relied upon. It is used for measuring continuously during the stroke of the piston the pressure in the cylinder, and recording that pressure on paper; the paper card being called an indicator diagram. The pencil which marks the card is connected by a lever with a small piston which moves up and down in a very small cylinder, the pencil having the same vertical movement; the travel of the pencil being three or four times greater than the piston. A small spring of known tension registers the action of the piston, and a small cock separates it from the cylinders, so when it is in communication with the cylinder it acts as a gauge, and when the steam pressure is cut off both sides of the piston are exposed to the atmosphere, the pencil thereby indicating the atmospheric pressure; the top of the piston is always exposed to the atmosphere. The paper drum which holds the cards, as may be seen by the illustration, is revolved upon its axis by a cord, which receives its motion from the cross-head, being transmitted by means of a fulcrumed lever, a cord being attached to the lever at such a point as will give the drum a proportionate travel to the stroke so diagrams of any desired size may be taken; a reducing wheel is in use which may be adjusted for any stroke. A 4″ diagram is about right for locomotive practice. The height of the diagrams will be controlled by the tension of the spring used, each spring being marked. The numbers on the spring signify that a vertical movement of the pencil of one inch is accomplished by a pressure per inch in the cylinder equal to the number on the spring; but in practice springs numbered one-half as high as boiler pressure are used. An adjustable spring adapted to any speed or pressure is also in use. By recording the pressure on the piston during a complete stroke we are able to determine the expansive force of the steam and also to discover any back pressure which may

be in the cylinder, and thereby determine the horse power exerted by the engine, and discover any irregularities in a correct distribution of the steam, which could not be done without the use of the indicator. It is not·so difficult to learn to operate the indicator as many men believe; it is a delicate



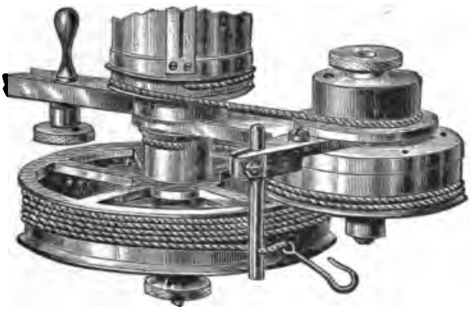
THE CROSBY INDICATOR.

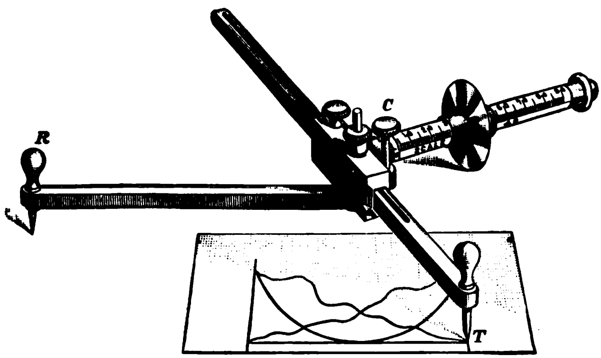
instrument, but only requires a little study, careful handling, and good judgment.

IMPROVED REDUCING WHEEL.

This reducing wheel is designed for attaching to any indicator. It will work on all strokes from 8 inches to 6 feet. It

saves all the labor required in setting up the old forms of reducing motion, and gives a perfect reduction. It is claimed it will operate up to 500 revolutions.





AN IMPROVED PLANIMETER.

The above engraving represents a new form of planimeter, which has been designed to obviate the defects which exist in other instruments of this class.

It will be noticed that the wheel has a knife edge, and is free to move on its shaft, so that there can be no slipping on the surface upon which it travels, giving the same results when used upon the roughest table, as upon the finest paper.

METHOD OF APPLICATION TO A LOCOMOTIVE.

The use of the indicator has become so common that the cylinders of all modern engines are drilled and tapped for its attachment by the builders. When drilling noles in the cylinder for indicator pipes two holes should be drilled, one at each end of the cylinder. They should be kept as near the ends of the cylinder as possible, so the piston will not close the holes when at extreme travel. When the cylinder has been bored out or worn as large as the counter bore and the clearance very small, a groove should be cut from near the end of the cylinder to the hole. The holes should be drilled on the outside of the cylinder about half way up the side for convenience, but never in the bottom of the cylinder, where there might be water. They should be tapped for a ¾″ pipe. In some cases the cylinder heads are drilled for this purpose, but the side is the best place as the pipe connection should be as short, and have as few elbows as possible. (When the engine is in service, the pipes must extend above the steam chest to clear bridges, etc.) The two holes should be connected with straight pipe, with a three way cock in the center, or T, and cock on each side of it, the indicator being attached to the T. One end of the fulcromed lever should be securely fastened to the running board and swing on a pivot; the lower end should be attached to the crosshead. When the drum cord is fastened to the lever, in the center of its travel the lever should always be at a perfect right angle with the cord. Pulleys should be avoided if possible.

DEFINITION OF TECHNICAL TERMS.

"Absolute pressure" of steam is its pressure reckoned from vacuum; the pressure shown by the steam gauge, plus the pressure of the atmosphere.

"Boiler pressure" is the pressure above atmosphere; the pressure shown by a correct steam gauge.

"Initial pressure" is the pressure in the cylinder at the beginning of the forward stroke.

"Terminal pressure" (t) is the pressure that would be in the cylinder at the end of the piston's stroke if release did not take place before the end of the stroke; it can be determined by extending the expansion curve to the end of the

diagram, or by dividing the pressure at the cut-off by the ratio of the expansion.

"Mean effective pressure" (M. E. F.) is the average pressure against the piston during its entire stroke in one direction, less the back pressure.

"Back pressure" is the loss in pounds per square inch required to get the steam out of the cylinder after it has done its work. On a locomotive it is shown by the distance apart of the atmosphere and counter pressure lines.

"Total back pressure" is the distance between the lines of counter pressure and perfect vacuum represented in pounds.

"Initial expansion" is shown by the reduction of pressure in the cylinder before steam is shut off.

"Ratio of expansion" would be the ratio of the fall in pressure between the cut-off and the end of the stroke, providing there was no exhaust.

"Wire drawing" is the reduction of pressure between the boiler and cylinder; it often causes initial expansion. It is caused by contracted steam pipes or ports.

"Clearance" is all the waste space between the piston and valve, when the piston is at the end of its stroke.

"A unit of heat" is the heat required to increase the temperature of one pound of water one degree Fahrenheit when the temperature of the water is just above the freezing point.

"A unit of work" (foot pound) is one pound raised a height of one foot. One unit of heat equals 772 units of work.

"One horse power" (H. P.) is 33,000 pounds lifted a height of one foot in one minute; or one pound lifted 33,000 feet in one minute or an equivalent force.

"Indicated horse power" (I. H. P.) is the horse power shown by the indicator. It is the product of the net area of the piston; its speed in feet per minute and the mean effective pressure divided by 33,000 pounds.

"Net horse power" is the indicated horse power less the friction of the engine.

"Saturated steam," called dry steam, is steam that contains just sufficient heat to keep the water in a state of steam.

"Superheated steam" is steam which has an excess of heat which may be parted with without causing condensation.

"Compression" is the compressing of the unexhausted steam into the clearance space by the piston after exhaust closure.

"Latent heat" is the quantity of heat expressed in heat units required to vaporize or evaporate water already heated to the temperature of the steam into which it is to be converted.

"Sensible heat of steam" is its heat as shown by a thermometer.

"Piston displacement" is the space reckoned in cubic inches swept through by the piston in a single stroke. It is found by multiplying the area of the piston in inches by its stroke in inches.

TAKING DIAGRAMS.

Diagrams should be taken from each end of the cylinder. This can be accomplished by adjusting the three-way, or other cock used, so as to place but one end of the cylinder in communication with the indicator at the same time. Each pair of diagrams should be taken under precisely the same conditions; in order to do this the operator should have an assistant in the cab who will watch the steam gauge and see that other conditions are the same. (An electrical appliance is now used whereby any number of diagrams may be taken simultaneously.) The indicator may be swung around to any desired position and the guide pulleys at the lower end of the drum may be adjusted to lead the cord fairly; adjust the cord to the proper length and see that the drum has the required travel. The paper should be so placed on the drum that the clips will hold it stretched smoothly, otherwise the diagram would be of no value. The pencil should be sharpened to a fine point and care should be taken that it does not bear too heavy on the paper—just sufficient to make a clear mark. When everything is ready remove the pencil from contact with the paper, open the cock and let the piston and cylinder warm up a little; then move the pencil up to the paper and hold it there while the crank pin makes a complete revolution. Then remove the pencil, close the cock, and immediately return the pencil and trace the atmospheric line. Then connect with the other end of the cylinder and repeat the operation. The conditions under which each diagram is taken should be noted on its back; speed, boiler pressure, etc. It is necessary that the operator should have the free use of both hands when taking diagrams, considering the position of the indicator and the rock motion of a locomotive when running at a high rate of speed, an enclosed platform is usually attached to the bumper beam for the operator's safety.

An indicator should not be attached to a new engine until it has run a day or two, as the sand or grit which might be lodged in the steam ports or pipes would ruin the indicator.

READING DIAGRAMS.

Having taken a diagram the next thing required is to know how to read it understandingly. The only positive information the diagram conveys is the pressure in the cylinder, but having a knowledge of the various operations of the valve, much additional information is derived through the process

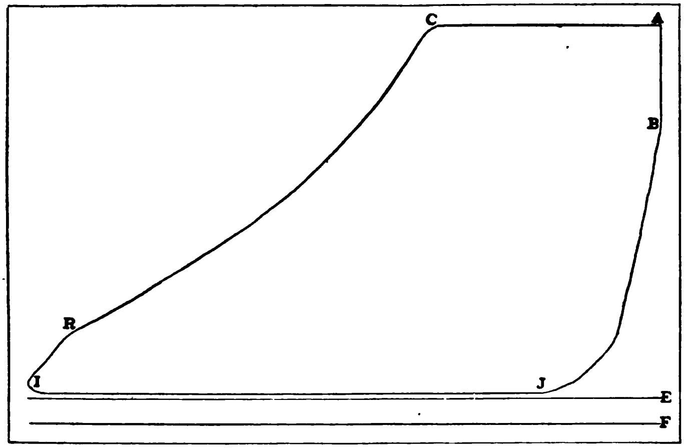


Fig. 1

of reasoning, the dimensions of the diagram being in a proportion to the dimensions of the cylinder. We will first refer to Fig. 1, and explain what the different lines signify. E represents the atmospheric line; this line has no connection with the conditions existing in the cylinder, it being made when communication between the cylinder and indicator is shut off and both sides of the indicator piston being exposed to the atmosphere as previously explained. It is the base from which all other pressures are determined. F is drawn by hand and represents a perfect line of vacuum, or no pressure, and it is made a distance below E equal to a scale of the spring, to the pressure of the atmosphere, which is 14.7 pounds per square inch at the sea level. A B is called the admission line; B

representing the point in the stroke at which steam is first admitted to the cylinder. A C is the steam line; beginning at A and ending at C; this line is kept up by the constant pressure until it reaches C, which is the point of cut-off, where the pressure begins to fall. C R is the expansion line; it represents the constantly decreasing pressure after cut-off, and caused by the expansion of the steam, while the piston travels a horizontal distance from C to R or from the point of cut-off to release. The exhaust line begins at R, which indicates the point of release or exhaust, and continues to the end of the stroke and the beginning of the return stroke. I J is the line of counter pressure; it begins at I and ends at J, where the exhaust is closed. J B is the compression line; beginning at J and ending at B it represents a rise in pressure being caused by the advancing piston compressing the steam which remains in the cylinder. The space between the different points are called periods, thus: From C to R is called the period of expansion. The admission line is sometimes considered as continuing from the point of admission to the point of cut-off, and the exhaust line from the opening to the closing of the exhaust port. No matter how carefully the valves may be adjusted by use of a tram, when the indicator is applied slight irregularities will invariably appear.

The pair of diagrams shown in Fig. 2 indicate a dissorted valve gear. In Fig. 1 the admission line is vertical, showing that the steam port had sufficient opening before the beginning of the stroke to fill the clearance space and retain its boiler pressure. (The pressure in the cylinder never quite equals boiler pressure, owing to its passage through cramped steam ports, etc.) A in Fig. 2 shows the steam line inclined in the direction of the stroke of the piston; this indicates delayed admission, as the piston should have full pressure at the beginning of its stroke. The distance the valve has moved before the piston receives full pressure may be determined by measuring the space marked C, and figuring proportionately, as you know the proportion the diagram is to the cylinder, and the stroke of the piston and the travel of the valve. Now if B was like A the eccentric would need to be advanced to increase the lead, but we find B has a full pressure at the beginning of the stroke and cuts off earlier in the stroke; it therefore has excessive lead. Therefore adjust the blades until admission and cut-off are as nearly equal as possible. If both diagrams were like B the lead should be reduced.

A in Fig. 3 shows too much compression; the valve closes the exhaust too early, and the pressure behind the piston is increased above steam chest pressure before the completion of the return stroke, then when the valve opens the pressure falls,

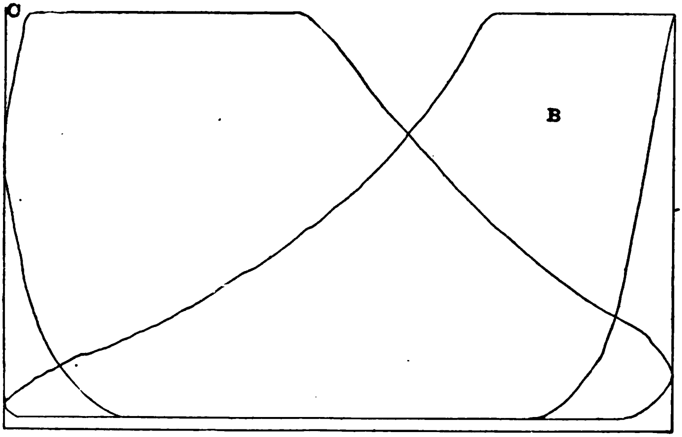


Fig. 2

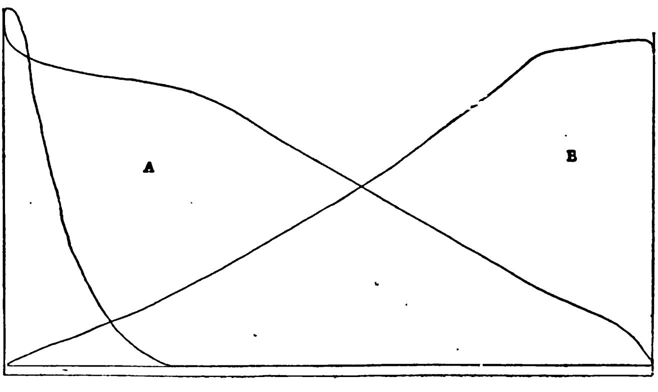


Fig. 3

making a loop in the diagram which sometimes causes valve to lift off the seat. Compression for slow speed locomotives need not be very great but B should always be higher than R as shown in Fig. 1. For a high speed, compression should be almost, if not quite, equal to steam chest pressure. B, in Fig. 3, shows no compression, the exhaust remains open until the piston has completed its stroke, which should never occur. Therefore the exhaust should be made to close later at A and earlier at B. If it is too great or too small when equalized, then the only remedy would be to change the inside lap of the valve. Back pressure will be shown by the distance apart of the atmospheric line and the line of counter pressure as shown in Fig. 1. Back pressure is largely controlled by the speed,

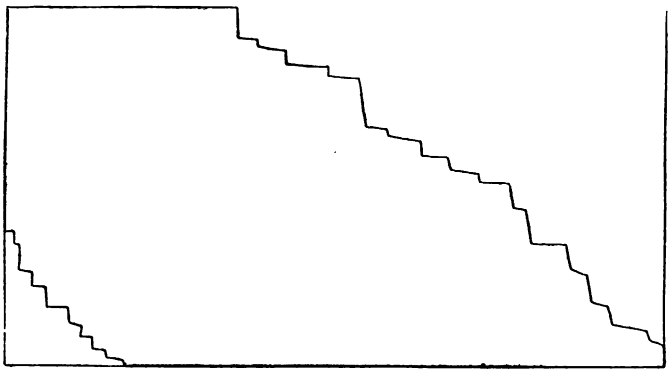


Fig. 4

design of the engine, adjustment of the valves, etc. Excessive back pressure may be caused by congested ports, or passages, or by late exhaust opening. An engine running at high speed in full gear will show an enormous back pressure. Water in the cylinders will also cause back pressure.

When the lines of a diagram look like the teeth of a saw as shown in Fig. 4 it is evidence that the friction in the cylinder causes the piston to stick; in this case the drum motion should be disconnected, leaving the indicator piston in communication with the engine cylinder for some time and keep it well oiled.

Fig. 5 shows a diagram taken from a freight engine with 18″x24″ cylinders; steam ports 1¼x17″ with ⅞″ outside lap of valve and 1-16″ inside lap and 1-16″ lead. Engine in full

gear, speed 12 miles per hour, boiler pressure 150 lbs., grade 30 feet per mile. This represents good practice, as the steam distribution is almost perfectly equalized.

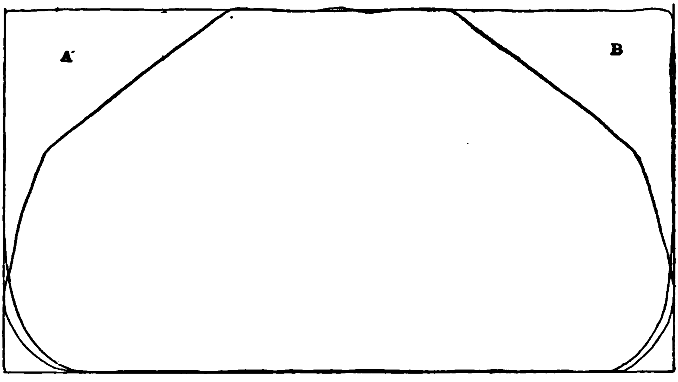


Fig. 5

Fig. 6 also represents good practice. These diagrams were taken from a passenger engine with one special car, at a speed of 60 miles per hour. The engine having 19"x24" cylinders, steam ports 1¼"x18", 13-16" outside lap, no inside lap, 1-32" lead, in full gear, reverse lever in center notch.

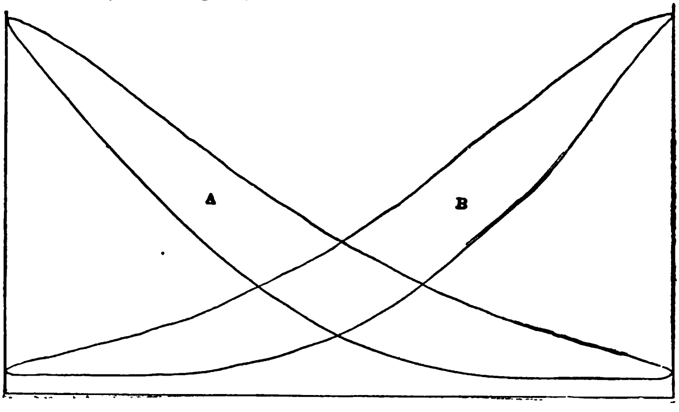
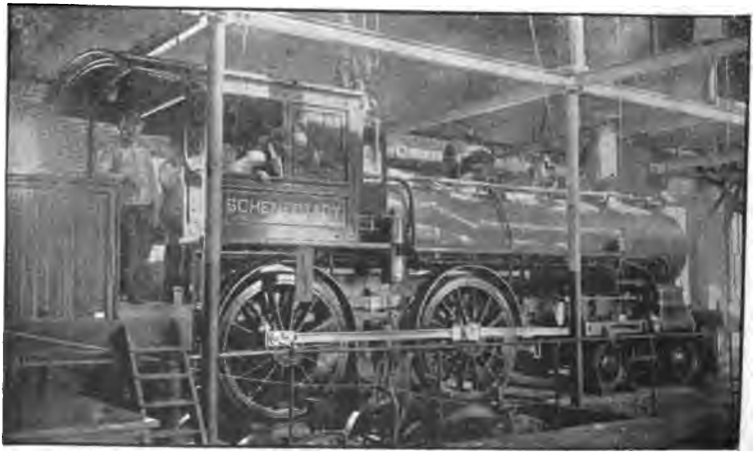


Fig. 6

LOCOMOTIVE TESTING PLANT.*

The testing plant is comparatively a new invention, and as there are very few of them in use a large majority of railroad employes have never had an opportunity of seeing one in operation, and do not understand their construction or the results which may be obtained by its use, we have therefore



LOCOMOTIVE TESTING PLANT, PURDUE UNIVERSITY.

thought it advisable to give a complete description of one and explain its many advantages. One or two railway companies have constructed plants for their own use, and we believe from present indications others will soon do likewise, for their en-

*We are indebted for this concise statement concerning the facilities for testing locomotives at Purdue University, to Mr. Wm. F. M. Goss, Director of the Engineering Laboratory.

gines can be given a more satisfactory test than could be obtained by taking them out on the road or the yard to "brake them in" as formerly. As this machine is a product of the Purdue University of La Fayette, Ind., and their experiments have extended through the longest period of time and their results been the most complete and satisfactory, we have described their plant, and given results obtained by them, besides showing their own locomotive "Schenectady" mounted in working order.

A FEW OF THE RESULTS ASCERTAINED BY ITS USE.

The traction dynamometer records the draw bar stress under any load.

A small dynamometer shows the power required to move the valves.

Indicators show the steam distribution in the cylinders and the pressure in the steam chest.

A caliorimeter shows the dryness or otherwise of the steam.

The speed recorder denotes the speed attained, while a very sensitive indicator (resembling a steam gauge) indicates the speed at all times.

Gauges indicate the rarification of the smoke box and ash pan.

The heat of the smoke box gases is ascertained with a pyrometer.

The counterbalance is tested and the valves adjusted to secure the best results, the coal consumed being weighed and the water measured. All experiments are based upon economy. The results showing units of work performed per ton of coal per horse power hour.

PRINCIPLES UNDERLYING PLAN OF MOUNTING.

The plan of mounting a locomotive for experimental purposes, in its inception, involved (1) supporting wheels carried by shafts running in fixed bearings, to receive the locomotive drivers and to turn with them; (2) brakes which should have sufficient capacity to absorb continuously the maximum power of the locomotive, and which should be mounted on the shafts of the supporting wheels; (3) a traction dynamometer of such form as would serve to indicate the horizontal motion of the engine on the supporting wheels.

Assume an engine, thus mounted, to be running in forward motion, the supporting wheels, the faces of which constitute the track, revolving freely in rolling contact with the drivers. The locomotive as a whole being at rest, the track under it

(the tops of the supporting wheels) is forced to move backward. If, now, the supporting wheels be retarded in their motion, as, for example, by the action of friction brakes the engine must, as a result, tend to move off them. If they be stopped the drivers must stop or slip. Whether the resistance be great or small the force which is transmitted from the driver to the supporting wheel to overcome the resistance will reappear as a stress at the draw bar, which alone holds the locomotive to its place upon the supporting wheels. The dynamometer constitutes the fixed point with which the draw bar connects and serves to measure stress transmitted.

It is evident from these considerations that the tractive power of such a locomotive may be increased or diminished by simply varying the resistance against which the supporting wheels turn, and that the reading of the traction dynamometer will always serve as a basis for calculating work done at the draw bar. It was believed that a locomotive thus mounted could be run either ahead or back under any desired load and at any speed; that, while thus run, its performance could be determined with a degree of accuracy and completeness far excelling that which it is possible to secure under ordinary conditions on the road; and that the whole apparatus would be extremely useful to students in steam engineering. It was not thought that every condition of the track would be perfectly met, but it was expected that the results obtained would prove valuable in extending a knowledge of locomotive performance. How far these expectations were justifiable the sequel will show.

THE DEVELOPMENT OF THE PLAN OF MOUNTING.

The matter of having a locomotive mounted for the purpose of experiment was discussed at Purdue early in the year 1890, and it was so well received that in May, 1891, an order was given the Schenectady Locomotive Works for a 17"x24" eight-wheeled engine. The details of the mounting were worked out during the two months following. In September the locomotive had been delivered and it was in operation before the close of the year. This plant, which is believed to be the first of its kind, is described in detail in a paper entitled "An Experimental Locomotive," which was read before the American Society of Mechanical Engineers at the San Francisco meeting in May, 1892. A second paper, "Tests of the Locomotive at the Laboratory of Purdue University," before the same society a year later, gives the results of twenty efficiency tests which were made during the winter of 1892-93. Besides the work involved by these elaborate tests, attention was given

to various matters of minor importance, among which may be mentioned the counterbalance problem. In the course of this latter work the fact that a driver, through the action of its counterbalance, will, under certain conditions, actually leave the track, was demonstrated by passing a wire under the moving wheel; wires thus passed at high speed came out with a portion of their length untouched by the wheel. It was also shown that a long pipe connection for an indicator such as is generally used in road tests, tends to enlarge the card given by the indicator as the speed of the engine increases. During the latter part of 1893 a very complete series of fourteen efficiency tests were run. These were made under full throttle and some of them at high speeds, the indicator showed from 300 to 700 horse power. The observed data obtained from these tests was of a very complete character and much was expected of it; but it was destined to serve no useful purpose. On the 23d of January, 1894, the Engineering Laboratory was burned. All experimental data which had not been published went up in smoke, and the locomotive went down in the wreck. The fire entailed a heavy burden of labor and expense. But with the new responsibilities which it brought there came also new opportunities. All details of the mounting mechanism were most carefully reviewed, and every fragment of experience was made to serve a useful purpose in the design of a new plant. The damaged locomotive was extricated from the ruin and delivered to the P., C., C. & St. L. R. R. Co., at Indianapolis, for repairs. Four months after the fire the new work had been completed and the reconstructed engine was in position. The following pages will serve to indicate the character of the new plant.

THE NEW PLANT.

The new plant occupies a building especially planned to receive it, and it is arranged for the accommodation of any locomotive, either steam or electric.

THE WHEEL FOUNDATION.

By reference to the second illustration it will be seen there is provided a wheel foundation of nearly twenty-five feet in length. This is more than sufficient to include the driving wheel base of any standard eight, ten or twelve-wheeled engine. For engines having six wheels coupled, a third supporting axle will be added to those shown, and for engines having eight wheels coupled, four new axles, having wheels of smaller diameter than those shown, will be used. The wheel foundation carries cast iron bed plates, to which are secured

pedestals for the support of the axle boxes. The lower flanges of the pedestals are slotted and the bed-plates have threaded holes spaced along their length. By these means the pedestals may be adjusted to any position along the length of the foundation. The boxes in use at present are plain babbitted shaft bearings, and between each bearing and its pedestal a wooden cushion is inserted. A bearing has been designed for use in some special experiments which provides for the suspension of the axle from springs, but this bearing has not been used. The outer edges of the wheel foundation are topped by timbers, to which the brakes are anchored. The brakes which absorb the power of the engine are the ones which were used in the original plant. They are constructed upon a principle developed by Professor Geo. I. Alden, and their capacity and wearing qualities are beyond question. The load upon them is controlled by varying the pressure of water which circulates through them and carries away the heat. The water pressure acts upon stationary copper plates which are forced against a moving cast iron disc, thereby producing friction. No provision is made for determining the load upon each brake, but the loads may be equalized by equalizing the flow and the pressure of the cooling water. The sum of these loads plus the friction of the axles in their boxes make up the sum total of work to be done; this work must be given out from the locomotive drivers. It all reappears in the form of draw-bar stress and its value is shown by the traction dynamometer. An elaborate system of piping (not shown on plate) provides for the circulation of the cooling water for the brakes at whatever point along the length of the foundation they may be located.

THE TRACTION DYNAMOMETER.

The vibrating character of the stresses to be measured makes the design of the traction dynamometer a matter of some difficulty. The dynamometer of the original plant consisted of an inexpensive system of levers attached to a heavy framework of wood, the vibrations being controlled by dashpots. In the present construction wood as a support is entirely abandoned and a massive brick pier, well stayed with iron rods, has been substituted. The dynamometer itself consists of the weighing head of an Emery testing machine, the hydraulic support of which is capable not only of transmitting the stress it receives, but also of withstanding the rapid vibration which the draw bar transmits to it. The apparatus is of 30,000 pounds capacity. In view of the enormous force which a locomotive is capable of exerting it would appear, at first sight, that an error of 50 or 100 pounds in the determination of draw

bar stresses would be of slight consequence, and that great accuracy in this matter is not required. Under some conditions this conclusion is correct, but under others it is far from true. The work done at the draw bar is the product of the force exerted multiplied by the space passed over; if the force exerted be great and the speed low a small error in the draw bar stress is not a matter of great importance, but if the reverse conditions exist—if the speed be high and the draw bar stress low—then it is absolutely necessary that the draw bar stress be determined with great accuracy. Moreover, high speeds necessarily involve low draw bar stresses. A locomotive which at ten miles an hour may pull 12,000 pounds will have difficulty; when running sixty miles per hour, in maintaining a pull of 2,500 pounds. These conditions have prompted the Purdue authorities to make extraordinary efforts to secure accurate measurements at the draw bar, and they serve as a sufficient justification of the heavy expenditure involved in the purchase of the Emery machine. The arrangement of the hydraulic support of the Emery testing machine permits the weighing scale to be at any convenient distance from the point where the stresses are received. The draw bar connects with this apparatus by a ball joint, which leaves its outer end free to respond to the movement of the locomotive on its springs. A threaded sleeve allows the draw bar to be lengthened or shortened for a final adjustment of the locomotive to its position upon the supporting wheels; and, finally, to meet the proportions of different locomotives, provision is made for a vertical adjustment of the entire head of the machine upon its frame.

THE SUPERSTRUCTURE.

The open space between the wheel foundation is of such dimensions as will easily accommodate an engine having a long driving wheel base, movable or temporary floors being used to fill in about each different engine, as may be found convenient. The level of the "tender floor" is at a sufficient height above the rail to serve as a platform from which to fire. At the rear is a run-way leading to the coal room, the floor of which is somewhat lower than the tender floor. A platform scale is set flush with the floor at the head of the run-way. During tests the scale is used for weighing coal which is delivered to the fireman. The feed water tank, from which the injectors draw their supply, is in the lower right hand corner. Above this supply tank are two small calibrated tanks so arranged that one may be filled while the other is discharged. A steam pump on the visitors' floor is for the purpose of supplying water under pressure to the friction brakes which load

the engine. The conditions under which the engine is operated are at all times within the control of a single person, whose place is just at the right of the steps leading to the tender floor. From this position he can see the throttle and reverse lever and observe all that goes on in the cab. At his right is the dynamometer scale-case, wherein it shows the load at the draw bar; in front are gauges giving the water pressure on the brakes; and under his hand are valves controlling the circulation of water through the brakes. No attempt has been made in this drawing to show small accessory apparatus, neither does it seem necessary to give an enumeration.

THE BUILDING.

A separate building is used for the locomotive testing plant. The entrance, which opens upon the visitors' floor, is approached from the general laboratory 150 feet away. The roof is so constructed that the upper end of the locomotive stack is made to stand outside of the building. The roof sections may be entirely removed and a door in the cross-wall, which extends between the removable roof and the main roof, provides ample height for the admission of the locomotive to the building. A window in this door serves to give the fireman a clear view of the top of the locomotive stack from his place in the cab, a condition which is essential to good work in firing. Above the stack is a pipe to convey the smoke clear of the building. To meet a change in the location of the stack this pipe may be moved to any position along the length of the removable roof. It is proposed to embody in this pipe a simple form of cinder trap which will catch and hold the sparks thrown out by the locomotive.

THE PURDUE RAILROAD.

In the process of establishing the first plant it was necessary to move the 85,000 pound locomotive "Schenectady" across wheat fields and pastures for a distance of one and one-quarter miles. Now Purdue has a track of its own connecting the locomotive laboratory with the railroads of the country. Locomotives may now be received and delivered without difficulty. For example, when the university engine was returned after being repaired at Indianapolis it was put under its own steam and backed in on the Purdue track directly to its place over the supporting wheels of the testing plant. The track will also serve to bring in supplies of every sort.

CYLINDERS.

HOW TO BORE OUT IN BORING MILL.

New Cylinder.—Set tool by inside of cylinders, and run tool through and see if there are any low or warped spots; then see if the inside face of the cylinder will plane off the required size; if it is all right then bore out to required size; then bore out counter bore at each end about ⅜″ deep. Get the length between the faces, and face off the ends. If the tool chatters, hang a weight on the end of the bar.

In Lathe.—Clamp two large blocks onto your carriage and bore them out to the same circle as outside diameter of rough cylinder; then clamp the cylinder onto the blocks and proceed to bore them out the same as in boring mill.

BORING OUT OLD CYLINDERS WITH BORING BAR.

Set bar central at each end by counter bore; or if back head is up, use taper gland in stuffing box. If cylinder is worn out very bad, take two cuts; use a coarse feed on first cut and a fine feed on the second cut. Recounter bore each end (if it needs it) with offset tools. If the tool chatters, hang a heavy weight on the back end of the boring bar. The reason a cylinder is counter-bored is to prevent the piston wearing a shoulder in the cylinder, the counter-bore should be made a sufficient length so the outside edge of the cylinder packing ring will just travel over the inner edge of the counter-bore. It should be made about ¼″ deep.

Small engines and motors are often used in the round house to drive the boring bar. Steam is sometimes taken from the locomotive for this purpose.

HOW TO TURN A BUSHING FOR A CYLINDER.

Clamp two large blocks onto the carriage of the lathe, and bore out wood the exact size of outside of bushing when rough; then clamp your bushing onto those two blocks; use a boring bar and bore out to the required size. Then set your bushing

onto a large mandrel with set-screws, and set so as to run perfectly true with the inside at both ends. Then turn off and fit outside; make it 1-128″ larger than the exact size of the cylinder inside. The long bearing will make it tight enough. Draw it into the cylinder with large screw-bolts and clamp, or drive it in with a large block. Use judgment and don't crack the cylinder. Make steam-tight joints on each end, so the cylinder heads will hold it intact; if not, you had better drill and tap a few holes and put in brass plugs through the cylinder and the bushing to hold it.

HOW TO PLANE UP A NEW CYLINDER.

Set the inside face square with the bed of the planer. Put a center in each end of the cylinder, and set each center perfectly true with the tool. Now plane the inside face to one-half the width the cylinders should be from center to center. Plane the top of cylinder outside of seat; then turn cylinder around, one-quarter turn. Set the inside face square with the bed of the planer up and down, and set two centers in the cylinder perfectly square across the bed of the planer; use square from center to square line on bed. Now finish the valve seat and the outside of it. Now turn the cylinder over and plane the bottom square with the inside face, the same distance from center of cylinder as the other cylinder, mate to it.

When taking a cut down the inside face of a cylinder, or a side cut on any other piece of work, always adjust the circle head of your planer slightly to one side (whichever side you are planing on), so tool won't drag.

HOW TO BOLT TWO CYLINDERS TOGETHER.

Set the back faces true with a long straightedge; level up both seats with a spirit level; see that the bottom faces are true for the center casting; make centers in cylinders at each end tram.

HOW TO FACE JOINTS ON OLD CYLINDERS.

Some shops have a small machine with cross feed that can be clamped onto cylinder head studs; it saves much scraping.

HOW TO GRIND CYLINDER HEADS.

When possible, up-end the cylinder, fasten a board or pole onto head and grind it, using No. 2 emery, with oil. If you

cannot up-end the cylinder use a brace and set ratchet or screw jack against it or long rod through cylinder.

Fitting Cylinder Saddles.

WHEN SMOKE ARCH IS TO BE RIVETED TO BOILER.

Let the arch rest on the saddle of cylinders in proper place; now level boiler with cylinders, with spirit level used on valve seat and on ring for the dome cap, also on shell of boiler. Now line both cylinders and divide fire box central with cylinder lines. Now drop plumb line over wagon top of the boiler and keep fire box plumb with the lines on both sides.

Now, if the saddle will finish so as to hold the boiler proper height up and down, lay off the saddle with hermaphrodites, as follows:

Set hermaphrodites under the center of the smoke arch, with points perpendicular with the center of the smoke arch. Now scribe a line all around at both ends and on both sides, and be careful to hold your hermaphrodites in the same perpendicular position all the way around.

Now separate boiler and saddle, and chip saddle down to a good bearing; use a straightedge to chip to lengthwise. When you have finished put some red lead on the saddle and bolt down solid.

If the circle of the saddle is too large for the boiler, and will not true up, put in a sheet iron or boiler plate liner, and figure on the thickness of the same when laying it off.

WHEN SMOKE ARCH IS TO BE FIRST BOLTED TO CYLINDER.

Some of the larger shops have a boring bar for this purpose, but you can lay it off as follows: Clamp board up at front and back end of saddle to be used for center of smoke arch; tack a piece of tin on each for a center. Now get the outside diameter of smoke arch and carry a line up on one board from lowest point of saddle, that distance. Now put four centers in your cylinders and set trams for cylinder center to a point where both marks will cross, exactly on the line you have carried up on one board from saddle; mark a small center at that point. Keep your trams set to same length and scribe two lines from center of cylinder at the other end, and make another small center where these lines cross.

Now you have both centers, so set your trams to one-half the outside diameter of the smoke arch and scribe a line on

each side of the saddle. Set a straightedge on the outside of saddle on each side, and set to each line, and scribe a straight line.

Now it is laid off, so take down your wooden centers and chip to your lines. When you have finished bolt your smoke arch solid to saddle. Set boiler perfectly central between frames at back end, and perfectly level both ways. Then have arch riveted to boiler.

WHEELS AND AXLES—QUARTERING.

NEW WHEELS AND NEW AXLES.

Quarter Axles in Lathe.—To do this scribe a large circle on face plate of lathe and divide into four equal parts and prick punch each quarter.

Now use post or solid tram from bed of lathe and set to one of your four centers; put sharp-pointed tool in tool post, run carriage along and scribe a fine line, the full length of the fit on right end of axle. Now turn lathe one-quarter turn ahead and set to next center, then scribe another line on left end of axle.

These two lines indicate the center of your key, so lay off key-ways required size.

Now put two centers in your wheel (after holes are bored out), one in center of crank-pin hole, and one in hole for shaft; carry straight line through both centers, which indicates center of key-way in wheel; now lay off your key-ways in wheel the required size.

Old Wheels and New Axle.—Place axle on two trestles or horses; drive each wheel on shaft with large block. Right crank pin hole one-quarter turn ahead of left crank pin. Use spirit level and set centers of crank pin hole and center of wheel perfectly horizontal on one side and vertical on the other, then scribe key-way on shaft.

With Crank Pin Intact.—If old crank pins are still in wheel, caliper size of collar on pin and put circle on shaft the same size and work from that instead of the centers.

Old Axle and New Wheel.—Set wheels same as before and scribe key-way in new wheel.

HOW TO BORE OUT CRANK PIN HOLES.

Most large shops have a quartering machine for this purpose. The two sides of the bed are at perfect right angles, with a head and boring bar on either side. So it is impossible to bore the holes out of square. The heads are adjustable so the stroke can be changed if desired.

When there is no quartering machine, the large face plate on the wheel lathe is usually quartered with four large holes drilled in it for dowel pin, and small boring bar fastens onto carriage of lathe.

HOW TO TRUE UP BEARINGS ON OLD CRANK PINS IN HUB.

There is a small machine for this purpose, to turn by hand. A center enters center in pin, and set screws fasten to inside collar; three dogs rest against inside of outside collar.

CAST STEEL WHEEL CENTERS.

A great many of the large driving wheel centers for modern passenger engines are now made of cast steel. With this kind of a wheel center the weight is greatly reduced, while the strength is increased.

Modern Counter-Balancing.

This is done after the wheels have been pressed on the axle. Reason will teach you that there is no such thing as having an engine counter-balanced perfectly at all times, for the simple reason that steam is the power, and if balanced perfectly when using steam it will not be perfect when the steam is shut off, as the steam carries the piston-head, cross-head, etc. The object is to balance the wheels as near as possible when running and overcome a part of the strain on the pin when shut off. But to counter-balance the parts approximately correct, so that excessive strain will not be imposed, is quite possible; care must be exercised to avoid too heavy a counter-balance, as it would give an excessive rail pressure.

SOLID COUNTER-BALANCE CAST IN WHEELS.

First find the center of gravity in counter-balance and see how far it is from center of the wheel. To get this take a

board any thickness and scratch the exact shape of counter-balance, then saw it out and balance it perfectly on a straight edge, on right angle with the crank pin. Scribe a line on each side of your straightedge, then find the exact center between your two lines; also central lengthwise. (See Fig. 1.) Now clamp your board up against counter-balance, set perfectly true, and measure from center on the board to the center of the wheel, say 18″. This distance indicates the distance to center of gravity. (It is impossible to find the exact center of gravity.)

Another, and perhaps a better way, is the string method.

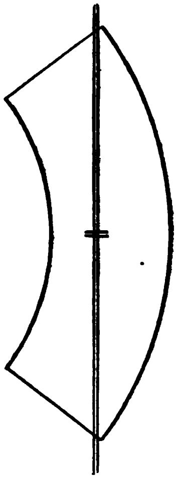


Fig. 1.

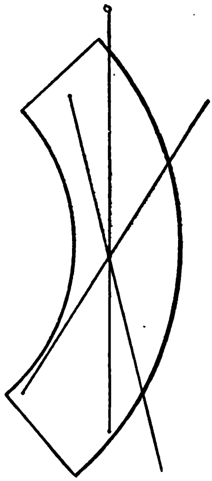


Fig. 2.

After you have a thin board or a pasteboard cut out the exact shape of your counter-balance, drive three pins or nails into it at any three places—usually two at one end and one at the other. Now suspend your board or let it hang from each of those three points, and mark it each time with a chalked line, letting line hang from same point. The point where the three lines cross each other indicates center of gravity. (See Fig. 2.)

Now place your pair of wheels on a horse or trestle, for this purpose (most shops have a trestle, with rails or iron flanges on top, for this purpose; if you have not, then level up two rails properly supported), and let one journal bearing rest on each rail. We will presume the crank pins are intact, if

not you must figure on their weight. Circle the diameter of the collar of pin on each end of the main shaft, and clamp a straightedge, or board, true with the circle on the shaft and the collar of your pin.

Now mark the board 18″ out from the center of the wheel, which is the distance to the center of gravity.

Now place the opposite pin on top center, draw another circle on the end of shaft, the size of the collar on pin. Drop a line around the pin and set perfectly true.

Now set a stick, or piece of iron, to center of gravity marked on the board, and let the other end rest on scale, and mark down the weight.

Now weigh each rod that fastens onto that particular crank pin, including the rod strap, brasses and all. Then weigh all the reciprocating parts, which include the main rod, cross head, piston rod, piston head and all movable parts. Now that you have found the weight of the counter-balance and also the weight of all parallel rods and the reciprocating parts you must be governed by the formula which we have herewith shown. and add on or subtract weight from the counter-balance as may be necessary. This may be done by drilling out solid metal or pouring in lead or attaching additional counter-balance plates.

There are nearly a score of different empirical rules in use for balancing and the results obtained by them have varied all the way from very good to very bad.

The two-thirds proportional weight of the reciprocating parts to balance as given in our formula was carefully computed as a result of recent scientific experiments upon the testing plant. While this proportion is subject to modification under certain circumstances, yet on a general average for all classes of engines it is considered perfect. For engines with very light reciprocating parts 50 per cent or one-half the weight of the reciprocating parts would be sufficient to balance, while upon compound engines with very heavy reciprocating parts 75 per cent or three-quarters of the weight should be balanced.

It is very essential that an engine should be balanced as nearly correct as possible, as an imperfectly balanced locomotive is very injurious to the road bed and track; it causes what is known as a hammer blow and it will cause the engine to jerk or pound, and recent experiments have proven that the wheels sometimes lift off the rails.

WITH COUNTER-BALANCE PLATES.

If your wheels have no counter-balance cast in them, find the amount of the weight that goes on the pin, the same as be-

FORMULA FOR COUNTERBALANCING.

Report of Counterbalance in Engine No. ______________________ **Shops,**

______________________ 189__.

RECIPROCATING PARTS.

	Lbs.
Weight of Piston, Packing Rings and Crosshead, complete, ...	______
Weight of Front End of Main Rod, complete, ...	______
Total Weight of Reciprocating Parts, ...	______
$\frac{2}{3}$ Weight of Reciprocating Parts, ...	______
Counterbalance on each Wheel for Reciprocating Parts, ...	______

WEIGHTS TO BE COUNTERBALANCED.

FRONT WHEEL.		MAIN WHEEL.		BACK WHEEL.	
	Lbs.		Lbs.		Lbs.
Weight of Front End of Side Rod	______	Weight of Back End of Main Rod	______	Weight Back End of Side Rod	______
Proportion of Reciprocating Parts	______	Weight of Middle Connection	______	Proportion of Reciprocating Parts	______
		Weight of Front End of Side Rod	______		
	______	Proportion of Reciprocating Parts	______		______
Total weight to be balanced	______	Total weight to be balanced	______	Total weight to be balanced	______

CONDITION BEFORE RE-BALANCING AND CORRECTION.

	Present Counterbalance, weighed at Crank Pin.	Correct Counterbalance, weighed at Crank Pin.	Present Counterbalance, Light.	Present Counterbalance, Heavy.
Front Wheel,				
Main Wheel,				
Back Wheel,				

Counterbalance corrected as above.

____
Master Mechanic.

NOTE.—Divide two-thirds of the weight of the reciprocating parts on each side by the number of driving wheels on a side, and add quotient to weight of revolving parts on each wheel. Under Weights to be Counterbalanced Main Wheel, the "Weight of Middle Connection" to be used for six coupled engines, "Weight of Front End of Side Rod" for four coupled engines.

fore, and hang that amount onto the pin, then fasten on enough counter-balance plates, or enough lead, to make wheels balance perfectly.

HOW TO TURN UP AND FIT CRANK PINS.

First see that pin will true up to required size; put a large center in each end of pin and drill a small ¼″ hole about ½″ deep in each center; this is done to retain original center. Now face off outside end of pin perfectly square and cut a small groove around center to find center afterward.

Turn collar required size. Find distance pin should stand out and cut shoulder, then finish your bearings for brasses in proper place and required diameter; reverse pin in lathe and fit to hole. To do this (if your calipers are medium, say 6″ by 1-18″ thick), set inside caliper to exact size of hole, set outside pair to them and let outside pair drag 5-16″ over fit. That will give you about a 30-ton fit. Do not cut off inside center, but counter-bore about ¼″ deep and leave collar to rivet inside.

To find the diameter of a crank pin multiply the diameter of the cylinder by .234.

HOW TO TURN AND FIT DRIVING AXLES.

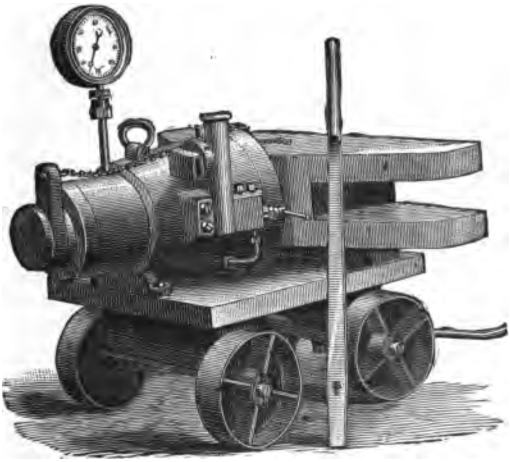
Put centers in each end, put in lathe and drill small hole in each center 1″ deep. Get length over all and cut off and face each end, and cut small groove on ends. Turn down to largest finished part, space off the fit for journal bearing, and space for eccentrics, and turn each to required size. Now cut down space between eccentrics about 1-16″ smaller than size for eccentrics, and fit same as crank pins, only let outside calipers drag about ⅝″ for 70-ton.

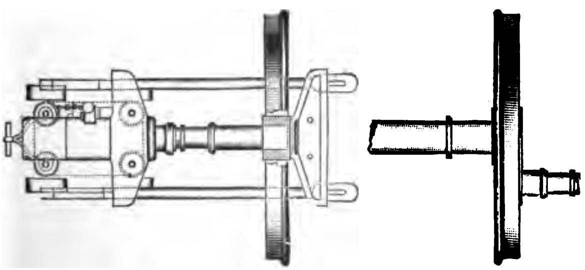
A VERY SIMPLE CRANK PIN GAUGE.

To press a crank pin out of a driving wheel to determine positively whether it is bent or how badly it is worn out of true is rather an expensive job. The most simple form of a gauge for this purpose that we have yet seen, consists of a small light V block which rests on the bearing and an adjustable band encircles the remainder of the bearing. An adjustable needle slips through the V block so the face of the wheel can be tried all around, or with a bent needle a circle may be drawn on the outer collar (or face) of the pin. The band can be adjusted to fit any sized bearing.

CRANK PIN PRESS.

This cut shows a plain, simple form of portable press for forcing crank pins in or out of driving wheels, while the wheels





are under the engine. The second cut shows the method of attachment and operation. It is a very useful tool.

HOW TO FIT DRIVING WHEEL KEYS.

The key-ways are usually straight. The key should fit on the sides, but should be 1-32″ loose top and bottom. Plane up key accordingly, allow 1-64″ stock sideways for fitting and drive with small sledge. Keys are usually planed on the end of a forging which has a head or heel on it to back out with when too tight. Set a jack under end of key to prevent bending.

LATERAL BETWEEN HUBS.

On a smooth road bed 1-32″ is enough lateral between hubs of drivers, or truck wheels. On a rough roadbed 1-16″ should be allowed. Brass hub plates are most generally used to take up side play—although some roads use babbitt on hub or boxes.

If you have too much lateral motion between hubs, face off hubs and turn up and put on new brass hub plates, or put plates on outside of boxes; in either case fasten plates with screw bolts with counter-sunk heads, with top of head 1-16″ or ⅛″ below the surface. In some places a composition of babbitt metal is used which wears very well.

TURNING AND BORING OUT TIRES.

When you have a set of tires to turn, always look for flat spots. Caliper each tire and turn smallest one first, make all others the same size. When boring out tires allow 1-100 of an inch for each foot in diameter for shrinkage. Turn the tread and flanges to a gauge.

HOW TO LAY OFF SHOES AND WEDGES.

This is one of the most important jobs on an engine, and should be done right, as it will prevent breaking crank pins, cutting tires and avoid trouble with driving brasses and rod brasses.

It is very essential that the center casting should be set perfectly central between the frames. as it leads the engine, and if out of center will most probably cause tires to cut.

There are many ways to get a square line on the frames to lay off shoes and wedges by. First, the fish-tail tram; three-pointed tram; lining center casting; lining one cylinder or both cylinders. But the best and most mechanical way is to line both cylinders, as it keeps main shaft square with cylinders.

HOW TO SET A CENTER CASTING.

Place in the center of the cylinders, front and back, and set perfectly central between the frames, then ream or rosebit holes and fit bolts.

HOW TO FILE UP JAWS ON ENGINE FRAME.

Use black lead on a face plate or straight edge, and file perfectly true up and down and keep square with outside of frame. Use a scraper and bring it to a good bearing, then fit shoes and wedges to jaws.

PORTABLE MILLING MACHINE FOR FRAME JAWS.

A very neat and handy tool for milling locomotive frame jaws while in place is in use at the Big Four shops at Urbana, Ill. It consists of a frame which carries a spiral fluted milling cutter, a worm and worm wheel and suitable gears. It may be clamped to the frame and is capable of accurate adjustment. It may be driven by steam, air, electricity, rope transmission or hand power. One hundred and eighty revolutions gives a feed of one inch per minute. It is the invention of Mr. F. Davisson and has been in use about a year, and is said to be giving good results.

HOW TO LAY OFF AND FIT PEDESTAL BRACES.

If braces are new, first see that there is no unnatural strain upon any of the jaws. By that we mean if engine is blocked under fire box or under center of frame; set another jack under back end of frame and divide the weight. Now try each face of frame where brace or binder fits, and see if they are perfectly square with outside face of frame. If so, then clamp the brace or binder up against the outside of the frame, and set it exactly as it should be when finished. Then scribe it all along for slotting.

When slotting let the lines on brace be visible when finished to allow for fitting with file. Now you are ready to fit binder. Put a small center at bottom end of jaw on outside of frame, and use a solid tram and scribe a line on opposite jaw. Now fit to a good bearing all around, and make your line tram right when finished. If old braces, have blacksmith close them wherever they are loose, and fit them the same way as new ones. If cast iron braces between jaws, use tram same way and be careful not to spring frames; if too loose rivet a liner on one end and then fit.

HOW TO FIND THE CENTER OF JAWS.

If front jaw is straight, or at right angle with top of frame, and back jaw tapers, carry a line true with face of front jaw, and mark on outside of frame above the jaw; then use hermaphrodites from the top of the frame and carry another line parallel with top of frame through the other line and center of jaw. Now measure the width of jaw at top of the wedge, set dividers to one-half that width, and carry back from front line to center of jaw. This keeps shoe and wedge the same thickness at the top. If both of the jaws taper, carry a line true with each face and find the exact center between them.

HOW TO LINE A CYLINDER.

When you line a cylinder don't use a clothes line, as so many "so-called machinists" do—learn to work close on everything. Use as fine a line as possible that will withstand the strain, and always set your line from the counter-bore of cylinder, and never from the worn part of the cylinder, and see that counter-bore is scraped clean before you set line by it. If the back cylinder head is up, set back end by stuffing box.

HOW TO GET SQUARE CENTER.

Line both cylinders and let line extend back of main jaws; use a six-foot square, or straightedge, and a two-foot square. Block the straightedge tight against the shoes, or front jaws, and keep same distance from top of frames on both sides. If it does not show square with cylinder lines, put a liner behind straightedge on one side until it is square. If the lines are out of parallel, divide the difference.

Now use hermaphrodites and scribe a line from straightedge on outside and inside of both frames, far enough ahead to clear the flange of the shoe.

Now set hermaphrodites from the top of the frame to the center of the straightedge, and carry a line through the other lines, on inside and outside of both frames, and put a small center in each one. Now carry a square line from the top of frame through each outside center and let line extend to bottom of frame. Now you have your square line.

HOW TO GET JAW CENTERS TO TRAM.

Get the center of all your jaws and mark them on the frame above. Now try the two main centers with square line, if out, move each center one-half the difference, and bring them square with your square line.

Now use long trams and make centers of the other jaws tram with your main jaws. (If solid, parallel, or side rods, get your length off of them.) If fire box sets down between frames, shorten your two back centers 1-32″ to allow for expansion.

NEW SHOES AND WEDGES.

Now if your shoes and wedges are all new, raise the wedges ¼″ above pedestal brace (to allow for pulling down), and put two pieces of tin on each piece of wood, and put wooden centers in all the jaws, placed perpendicular; carry a square line from the top of frame down through the center of all the jaws.

Now use hermaphrodites and carry a line through top and bottom piece of tin on the wooden centers and put a small prick punch in each. Now caliper box. (We will presume they are all the same size.) Now if you have a gauge to plane to add the amount of the gauge to half the size of the box; if not, request the planer man to plane 1″ above marks, and add 1″ to half the size of the box and scribe on all the shoes and wedges from the tin centers in jaws; put prick punch marks

on all of them, top and bottom. Now set dividers from prick punch mark on the main shoe to square line, and then carry it inside and scribe another line on the shoe from the inside main center. Set short tram from shoe to wedge outside and transfer to inside. Now if you can use a long tram inside to other shoes do so by setting the tram to center of jaws outside and transfer inside; if not, use a straightedge against the other shoes.

Set hermaphrodites to the prick punch outside and transfer to inside. Now use a short tram, or dividers, and set from the punch mark on shoe to the one on the wedge and transfer to the inside. Give planer three points to set by. Now you have finished.

TO LAY OFF MAIN SHOES FIRST.

The best, but slowest, way is to lay off both main shoes, first from square line on frame and have them planed and filed perfectly square across the face before laying off other shoes.

They are laid off in this way: If it is 10″ from center of jaw to the square line on the frame and the box is 12″ in diameter, the planed face of the shoe should be 4″ from square line. Now take off the amount of your gauge, or 1″, and lay off 3″ from the square line. (See Height and Depth measurement, page 224.) When shoes are planed and finished, try the pop marks with the gauge, or hermaphrodites set to 1″, and file until the pop marks are right with the face of the shoes; then set your long trams to the jaw centers and lay off the other shoes. If you cannot use a long tram inside, transfer with straightedge. When the shoes are all finished, caliper driving box, and chip and file a corner off the wedge until it calipers the same size as the box, then give three pop marks to set the wedge by from the face of the shoe, and put a small center on the spot that calipers the same size as the box; do the same on all wedges and you have finished. Be sure that you have the wedges raised ¼″ above the binder, or nut on the wedge bolt, when you lay them off, to allow for pulling down. If the wedge will not true up put in a liner. All boxes are supposed to be the same size; if they are not you must allow for it.

OLD SHOES AND WEDGES WITH BOXES AND BRASSES OF DIFFERENT SIZE.

Get square center, and centers in all your jaws and mark them on the side of the frame above the jaw, and keep all the jaw centers in tram, and true with the square centers. Now carry two lines on outside face of each box with transfer plate. Then put centers in all your boxes. Try all the boxes and see

if they are bored out central; if so, set your dividers to one-half the diameter of each box and scribe on frame each way from center of jaw. If any of the boxes are not central set your dividers from the center of the box to the forward line on the box, and scribe a line on frame in front of center of the jaw. Then set dividers again from center of box to back line on box and scribe on frame back of center of jaw. Now put up all the shoes and wedges and try with a straightedge, and see how much of a liner is needed for each to finish up to the size of the box marked on the frame, allowing about 1-32″ stock to plane off, and if you intend to plane liners inside, allow 1-32″ for that. Now rivet on all the liners, and put up all shoes and wedges again, and spread them with bolt and nut, or screw, solid against each jaw. Now if you are using a gauge to plane to, get the distance of gauge; if not, set dividers to 1″ and scribe a line each way from the size of the box marked on frame on main jaws only.

Now use a two-foot square—T square—or work from square line on frame and carry a square line down main shoe true with your 1″ mark on the frame above. Make pop mark near top, bottom and center of shoe, and transfer another pop mark to the inside with straightedge same distance from square center. Now set your long trams to the front face of each box marked on the frame (not the center of your jaws); and lay off the other shoes from main shoe. Set your long trams on each side of the engine—independent of the other side—and keep all your pop marks top and bottom the same distance from the top of the frame; transfer pop to the inside of the other shoes, the same as on the main shoe, providing you cannot use the tram on the inside.

Now have all the shoes planed up and lay off your wedges. Set each wedge ¼″ above frame (to allow for pulling down); use wedge gauge from face of shoe, or short tram from pop mark on shoe, and set to any size and make three pop marks on the wedge to set by on planer. Then set inside calipers to exact size of each box, and chip or file a spot on each wedge, and make another pop mark where it is exact size of the box. Set the wedge on planer to pop marks and plane off until tool just scrapes the pop mark on the face of the wedge.

To protect the man who lays off the wedges, use a small gauge from pop on face of wedge and scribe a circle on the outside flange on the wedge, which will be your proof mark.

LINERS.

When liners are needed they should be riveted solid to the shoe or wedge, using five or eight ¼″ rivets, and if the liner

is very heavy it should be trued up on the planer after it is riveted on.

The habit of placing loose liners behind shoes and wedges is false economy and is not practiced by any good workmen.

HOW TO PLANE UP SHOES AND WEDGES.

New.—Clamp on bed of planer face down and true up edge of flanges. Now turn them over and clamp flanges down, and keep sides true with tool. Now take light cut across face, just enough to true up. Now caliper driving boxes inside and finish both outsides, making shoe or wedge 1-64″ smaller than box. Now clamp all shoes down solid in chuck and finish inside; unless otherwise instructed make each flange same thickness, and make wide enough to slip over widest part of jaw. Now chuck all wedges and block up top end of each, so as to set inside faces true with tool, and finish flanges the same as shoes.

Old or New When Laid Off.—Set shoe or wedge by the pop marks on the outside, using surface gauge or hermaphrodites, and clamp down solid to face of planer. Line up until pop marks show exactly same height all around. Now plane off face to required size, and make plenty of fillet.

HOW TO PLANE UP DRIVING BOXES.

Clamp on bed of planer and finish on face, turn over, clamp planed face to bed and finish other face, making box the correct width. Now clamp one side against angle plate on bed of planer and plane out for shoe, making each flange required thickness and depth. Now reverse, and plane the other side the same. Now if you wish to bevel or taper flanges place a liner between box and angle plate and finish one end, then change the liner and finish the other end. Boxes are usually slotted for brasses, but if you have a circle feed on planer place all boxes top down on bed, clamp and plane to required circle. Keep all the boxes the same size when possible.

Bevel Inside of Driving Boxes.—On very rough railroads it is well to bevel inside of driving boxes (where shoes and wedges fit) at both ends, leaving about 4″ of bearing in the center; this saves flanges of box from breaking.

Circle Feed on Planer.—Some shops have planer head with circle feed, which is very handy for planing out driving boxes for brasses, as any number of boxes may be planed at once and all exactly the same size; it saves time and work for the slotter.

DRIVING BRASSES.

To Fit to Boxes.—In this you must be governed by the strength of your box. If it is a very light box and you are fitting a circle brass, four or five tons pressure will be sufficient. But if it is a very heavy box, from fifteen to eighteen tons pressure may be put on. For medium size driving boxes ten tons is the rule.

If gib brasses, three tons' pressure on each gib, be very careful not to file the brass tapering or you may burst the box.

To Bore Out.—Driving brasses should not be bored out until after they are pressed into box. You can bore them out in boring mill or lathe. Set perfectly central sideways, leaving all the stock possible in crown; bore the exact size of smallest part of journal, and keep oil cellar in box when boring out.

To Fit to Journal.—Always file out crown of brass about 3″ wide and scrape to a good bearing on sides. The weight of the engine will soon bring her down on crown. Leave no rough file marks on brass, and clean out oil holes. Don't let it bear on fillet. Let it move freely on journal when finished. A long board is generally used when fitting driving boxes, but in some shops where very heavy boxes are in use a block and tackle with a hook is used to raise and lower box onto journal.

RODS, BRASSES, ETC.

HOW TO FIND LENGTH OF MAIN ROD.

If guides and cross-head are up and main driving box set properly in jaw, place cross-head in exct center of guides and use a square from center of main driving box.

Place one end of a long stick against cross-head pin and scribe line on back end of stick square with center of main box; now add on one-half the diameter of cross-head pin and you have it.

If guides are not hung, or boxes not in jaw, place straight-edge across main shoes and get distance to face of back cylinder head. Now add one-half the diameter of main box.

Now substract the length of the front guide block clearance, and half the travel and the distance from front end of cross-head to center of cross-head pin. The remainder will be your length, providing the cylinder center and wheel center are on a horizontal line (see diagram on page 76). If they are not in the same horizontal line then the main rod must be made longer, how much longer may be determined by Height and depth measurement (see page 224.)

When adjusting a main rod to the proper length, you should always notice whether the key in the back end is in front or behind the crank pin. When in front you lengthen the rod as the brass wears and you drive the key down, and when behind you shorten it. Divide your clearance accordingly.

Another mechanical point to be considered is the space occupied by the area of the piston rod; when divided central the back end should have 1-32″ more clearance than the front end to equalize the exhaust. In the round-house it is sometimes necessary to disconnect a main rod and put it up again. When the engine cannot be pinched onto center, in this case scribe a line on the guides at either end of cross-head before you disconnect and see that cross-head is right with same line after you have connected.

LENGTH OF PARALLEL RODS.

If wheels are under engine, get length from wheel center. If not, take length from center of jaws (if boxes are same size and bored central), and in either case, if engine is cold when length is taken, make the back rods 1-32″ long to allow for expansion; providing fire box sets down between two back pair of wheels.

HOW TO GET WHEEL CENTERS AND CRANK PINS IN TRAM AND PUT UP RODS.

Plug up your wheel centers with lead and find exact center of each wheel, and try them with a tram. If they show out of tram, then try main centers with centers in rocker-arms and line shoes, and wedges wherever needed to bring into tram and also to keep square with rocker boxes (which are supposed to be right), also see that all your wedges are set up moderately tight before you tram main centers, and also notice if any of her tires are beginning to cut; if so, that wheel should be lined forward or opposite wheel back.

Now place pins on top and bottom eight, and jump wheels until they tram. If engine has more than two pairs of driving wheels and "M" pin is longer than others, set tram accordingly. (See Height and depth measurements, page 224.) Now, when pins tram, pinch one side of engine on dead center and put up rods on that side. Then pinch other side on dead center and put up that side. Line snug between pins.

When up, the front rods should work freely on pins, but if boiler is cold line the back rod tight between pins to allow for expansion of boiler. Each brass should have at least 1-64″ lateral. See that rods divide right sideways.

TO LOCATE WHICH PAIR OF WHEELS ARE OUT OF TRAM.

If you tram an engine and find wheel centers "out of tram," you should at once locate which pair is out. You may ascertain this by using inside calipers between frame and largest turned face of wheel inside, at front and back of wheel. Each pair of wheels should be square with the frame.

HOW TO FIT ROD BRASSES.

File out the top and bottom and give a good side bearing, but don't let them bear on the fillet. Key up brass to brass

in the strap and whirl on the pin, but take up all lost motion, or it may pound.

File the front end of the main rod brass open 1-32″, but on all others key up brass to brass. Use soap on hot pin.

FINISH ENDS OF RODS.

For convenience, finish the ends of rods, valve rods, etc., before welding, as they are more convenient to handle.

HOLES FOR OIL CUPS.

Always counter-sink all holes that are to be tapped for oil cups, so you can leave fillet on the stem of cup, which strengthens stem.

FORGED SIDE ROD CUPS.

On many roads where solid end side rods are in use, they forge the oil cup solid with the rod, then there is no danger of losing oil cups, the lid or cover being the only removable part.

ROD BRASSES.

Bore Out.—When finished a rod brass should have a good bearing front and back, but should not bear top and bottom, therefore put a piece of Russia iron between the brasses before boring them out, then key up tight and bore out 1-32″ larger than crank pin. Take out Russia iron when bored.

Solid Brasses.—Chuck collar and bore out 1-32″ larger than the pin, then turn the outside 1-32″ larger than the hole. Reverse and turn off collar. If pressed into rods, bore out in boring mill, making 1-64″ loose.

Eccentric Brasses.—Some roads use solid brasses in the side rods, which are turned eccentric shape and are capable of adjustment by simply moving a small lever which is secured to a quadrant, which is fastened to the rod. The short levers are adjusted while the crank pins are on center, thereby adjusting the length of the rods to suit the wheel centers on each side.

PLANE ROD STRAPS.

Finish one side, turn over and put a piece of tin under the end that goes on the rod, then finish that side. The tin makes a taper in the strap, so brasses will slip on easy. The inside of the straps are usually finished on a milling machine where there is one; if not, then on a slotter or planer.

GUIDES, CROSS-HEADS, ETC.

HOW TO HANG OR LINE UP GUIDES.

Four Bar Guides.—First put a center in your cross-head and set your guide gauge to it from bottom of head. Put up both bottom guides, then line your cylinders. (See Shoes and Wedges, page 140.) Line guides to your gauge up and down, and keep perfectly true and level with frames across face. Caliper your cross-head and get width apart; allow 1-32″ for lateral motion, or side play. Divide them central and keep perfectly parallel with line. Try three-foot straightedge on face lengthwise, and if out in the center, spring them with liners.

Now take down your line, put cross-head on and see that it does not rock at any point.

Now line down top guide as close as you can, just so head will work to and fro freely, and keep central. Now trim off your liners, remembering the strain is on top guide in forward motion.

Two Bar Guides.—Mogul.—Line cylinder; get distance from bottom face of cross-head gib to center. Set bottom guide that distance from line, caliper head and set top guide with calipers. Now use gauge on the sides and keep central with line and square with top of frame, and use square across face. Now slip in cross-head and get all liner you can under top gib, and cut oil holes in your liners. Put on outside plate and you are done.

Two Bar Above Cylinder Center.—Measure distance from top of cross-head to center of cross-head. Line cylinder. Set top guide first right distance from line, use a square on side and keep perfectly central with line and level with frames. Caliper head and set bottom guide right distance from top guide and perfectly central with top guide. Slip in your gib and line up close, then put up head.

One Bar Diamond Guide.—Put cross-head on guide and line close, then line cylinder and run line through cross-head. Move head forward and backward and line central both ways.

Line Up Old Cross-Head Gibs.—Use inside calipers between each guide and piston rod and put in liners wherever needed to keep piston central. Always cut oil holes in liners where needed.

TO LAY OFF NEW GUIDE BLOCKS.

Four Bar.—Line cylinder perfectly true, put center in cross-head and get distance to bottom of cross-head. Clamp two straightedges onto face of new blocks below the line and fasten to back cylinder head and guide yoke. Set straightedges right distance from line and keep perfectly level with cylinder, or top of frames, then scribe a line on blocks in front and behind. Now caliper wings of cross-head and set hermaphrodites to that size, and scribe a line from straightedges onto top of all four blocks; don't plane sides of blocks until you have put up two bottom guides and set them central and allowed for lateral or side play. Then scribe blocks on side.

Do likewise on other kinds of guides.

HOW TO GET LENGTH OF GUIDES.

Add together the length of both guide blocks, the clearance length of cross-head, and travel of cross-head.

CROSS-HEADS.

To Plane Up.—Clamp on bed of planer and finish the top and bottom and outsides, but leave about 1/8" stock on the wings that bear on the guides, also on the sides that fit between the guides, to be finished when keyed onto piston. To finish: Place two V blocks in grooves of the planer and clamp piston down, key on cross-head and set perfectly square. Now finish the head to the right size all around, letting the tool run over both wings without changing, and plane perfectly central.

Turn Up Solid Pin.—Some shops have a machine for this purpose, large and small gear, and it turns by hand. Small gear is in two halves, with a short tool and feed inside.

The old way: Use a tool made to a half circle and put a wooden pole in piston hole and turn and feed by hand in lathe, cutting one-half circle at a time; chip clearance for tool.

Mogul Pin.—Put center in each end and make it run true. Measure distance through head and add to it the thickness of your washer and two nuts and ½″ for the thimble point, and ¼″ for draw, and face off both ends to right length over all.

Now you must cut the three shoulders, measure from larger end of pin and make the first two the exact distance to shoulder on cross-head, but allow ¼″ draw on the outside shoulder. Now turn pin down to required size, and fit to holes in cross-head; when tight let shoulders stand off ¼″ to allow for draw, cut threads on the stem and fit nuts and washer.

STRAIN ON TOP GUIDE.

When the center of cylinder is between top and bottom guides, remember most of the wear is on the top guide, when in forward motion. The power is in the cylinder, and not in the crank pin.

STEAM CHESTS, VALVES, ETC.

HOW TO PUT ON NEW FALSE VALVE SEATS.

If the seat has wings that fit inside of the chest clamp the seat square and central with ports in cylinder. Screw in two steam chest studs in each corner and put up the steam chest, and mark the wings inside; then take them off and have the ends of the wings jumped off, or chip and file to lines.

If the seat has no wings drill and counter-bore about twelve or sixteen holes for screw bolts. Set the seat square and central with the ports in cylinder, letting heads of screw bolts, if iron, clear the face of seat 1-16″. If brass, leave flush with seat.

TRUE UP OLD VALVE SEATS.

If you have a valve facer, true up with it, and leave a small proof mark, but if you have no facer, and if the seat is out very bad, true up with a hammer and chisel; then use a bastard file until you get a fine bearing with the face plate or valve, then use a smooth file, or scraper, and bring it down to a good bearing. Keep the seat the same height all around.

LINE DOWN PRESSURE PLATES.

Get the height from the top of the valve to the seat for gasket, also the thickness of the chest outside of the gaskets. then find off-set of pressure plate if it has any, and if round gaskets ¼″ thick, allow 3-32″, and if it is a flat gasket, allow 1-32″ to draw down, and line the plates accordingly.

LAY OFF VALVE YOKE.

If slotted, fit to valve before laying off, and square up by edge of valve, but if not, set square both ways with yoke, try with surface gauge and see if stem will true up required size; use a surface gauge to get a center in each end and lay off yoke for valve with two-foot square, size of valve, allowing 1-16″ lateral in end.

TURN UP VALVE STEM.

Drill a small hole in end of stem, put in lathe, using a bolt and nut or screw jack in yoke to keep from springing. Cut off end right length. Now cut shoulder and fit to valve rod (same as fitting taper bolts), then turn down stem to required size.

PLANE UP VALVES.

Clamp valve on planer face down and true up top to set by. Now turn over and true up face of valve. Turn over again and clamp on parallel strips, find centers at each end, and set true with tool. Now face off top to required height, and plane off sides where yoke fits and outside edges of valve to required size and keep perfectly central, and keep bottom flanges of valve required thickness. Now use a square nose tool and cut two grooves for long strips, proper width and depth, and right distance apart, keeping perfectly central. Now set valve crosswise on bed, still using parallel strips and set perfectly square with bed. Now plane off outside ends right length and keep central, and cut end grooves for strips. Have inside of valve slotted, or lay off, chip clearance at each end and plane out.

PLANE VALVE STRIPS.

Clamp in chuck, top faces down and true up bottom lugs, turn over in chuck and finish top side, making same height as grooves in valve. Now chuck and true up one side of each, then turn over and plane off other side, fitting snug to grooves in valve. You must finish lugs on short strips in jumper, then measure distance between grooves on valve and jump off ends of long strips 1-32″ shorter to allow for expansion of long strips.

TRUE UP FACE OF OLD VALVE.

Clamp on bed of planer, top down, and true up. Use broad nose tool with course feed.

PISTON, PACKING RINGS, ETC.

HOW TO FIND LENGTH OF PISTON ROD.

If your guides and cross-head are up, set cross-head in exact center of guides, and get distance from front face of cross-head to inside of back cylinder head.

Now get exact distance between inside faces of cylinder heads. Now get distance from back face of spider or piston head to extreme front point, whether it is the heads of the follower bolts or nuts on end of piston. Add this to travel of cross-heads and see what clearance you have inside of cylinder. Now add one-half this clearance to original length from face of cross-head to inside face of back head and ½ the clearance.

This will give length of piston from shoulder to shoulder, then add on whatever you need on either end.

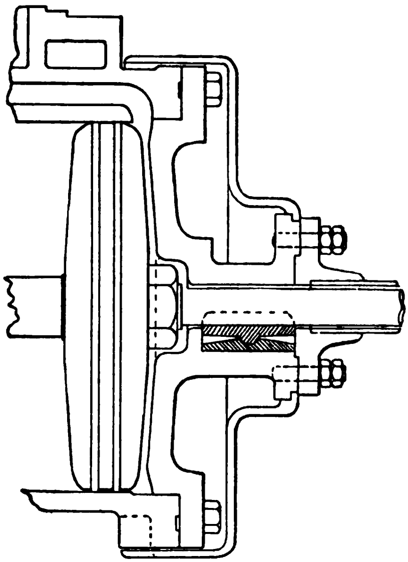
If back head is not up, add the thickness of back head, front guide block, one-half of the travel, and one-half the clearance on guides, and one-half the clearance in cylinder, and you have the distance from shoulder to shoulder.

Turn Up New Rod.—Put two deep centers in rod and put in lathe, use a square center and get each end to run true. Now replace square center with round center, use diamond point tool, and turn rod off to about 1-16" larger than finished size. Now measure distance rod should go into cross-head and cut a shoulder that length from end. Now caliper taper hole in cross-head at each end, and fit, same as to fit taper bolts (see how to fit taper bolts, page 173); allow 1-16" to grind and drive to shoulder. Now turn rod down to finished size, using very fine feed. Now take out tool marks with a lathe file, and polish rod with emery cloth, or emery paper.

Now reverse in lathe, cut other shoulder exact distance rod should be, and fit to piston head; let calipers drag ¼" for 20-ton pressure, then counter-bore end to rivet over. The diameter of a piston rod should be about 1-6 the diameter of the cylinder.

EXTENSION PISTON RODS.

Extension piston rods are used upon most all low pressure cylinders on compound engines, and on many other engines with very large, heavy pistons. They hold up the weight of the piston and prevent wearing the cylinders. The cut below shows the method of their application.



EXTENSION PISTON ROD.

TURN AND FIT PISTON HEAD, BULL RING, CYLINDER PACKING RINGS, AND FOLLOWER PLATE.

Use Universal Chuck.

Piston Head.—Chuck, bore out hole for piston and ream with large reamer, turn outside, or largest part 1-32″ smaller than cylinder, reverse in chuck, turn off lugs and true up both faces to required size and leave collar for follower plate.

Bull Ring.—Chuck, bore out about ⅛″ larger than outside of lugs on piston head, turn off 1-32″ smaller than cylinder,

turn outside flanges 3″ smaller than largest part, face off 1-64″ wider than distance from one face of piston head to other, just enough for follower plate to clamp bull ring without cracking plate. If solid bull ring, chuck and face off one side, reverse in chuck and face off right width, bore out 1-16″ larger than lugs on piston head and cut grooves proper width and 1-16″ deeper than size of packing rings.

Packing Rings.—Caliper cylinder. Make outside of packing rings 3-16″ larger, if the two diameters of bull ring differ 3″, then make packing rings about ¼″ less, therefore bore out packing casting 2½″ less than outside of same; use square nose tool and cut off rings right width. Dunbar packing, which is one narrow flat ring and an L ring sawed into many pieces and set out against the cylinder with a flat spring, is considered the best but most expensive cylinder packing in use; it will fit a cylinder that is worn out of round better than any other kind. It is used on many roads.

Follower Plate.—Chuck and face off true, turn off outside 1-32″ smaller than cylinder, and face off holes for follower bolts.

TO FIT UP BULL RING, PACKING RINGS, ETC.

First—See that follower plate clamps bull ring when tightened, put one dowel pin on each side of bull ring about 4″ apart, and when you place in the cylinders put dowels to the bottom.

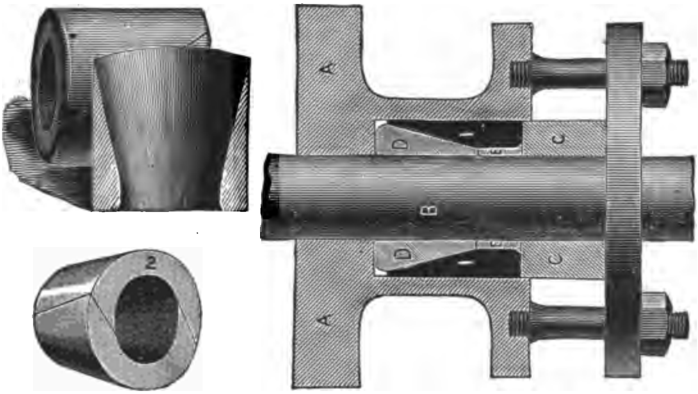
Saw out of packing rings three and one-seventh times the difference between size of cylinder and outside of packing rings, and see that they clear dowel pins and slip through smallest part of cylinder. If no dowel pins are used saw rings so they will lap. Put in piston head, or spider, bull ring and packing rings and line up piston head central with cylinder, placing liners between bull ring and lugs on piston head, then put on follower plate and tighten up follower bolts.

DRAW FOR KEYS, SUCH AS PISTON OR VALVE STEM KEYS.

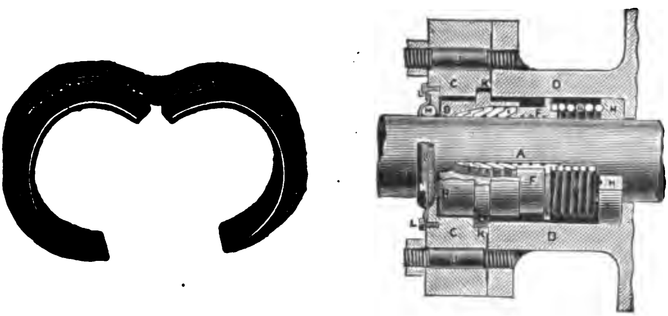
Find out the length of key and width at each end and how much taper to one inch, then see how much you will have left to drive, and multiply by the amount to the inch, then allow about 1-32″ for filing out, if keyway is to be drilled.

METALLIC PACKING.

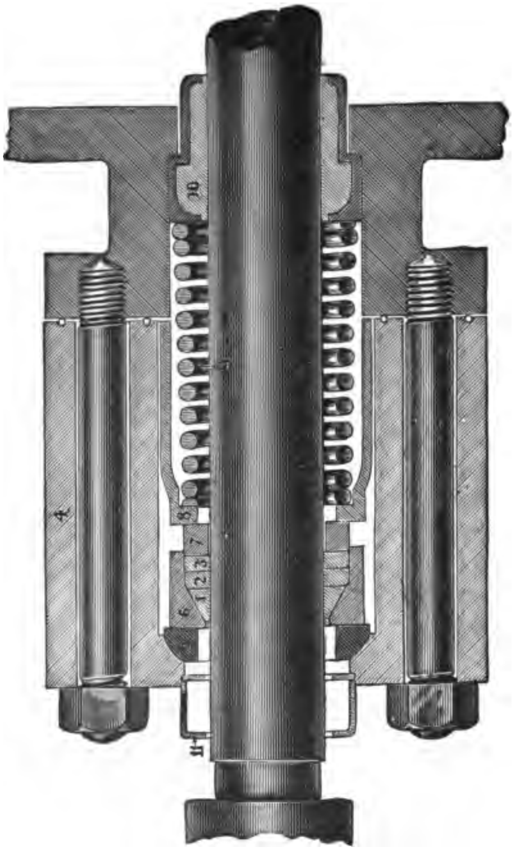
Since the advent of metallic packing the use of hemp and asbestos has been almost entirely discontinued in locomotive service, the metallic packing giving much better results and wearing longer with less attention or trouble. It is used upon



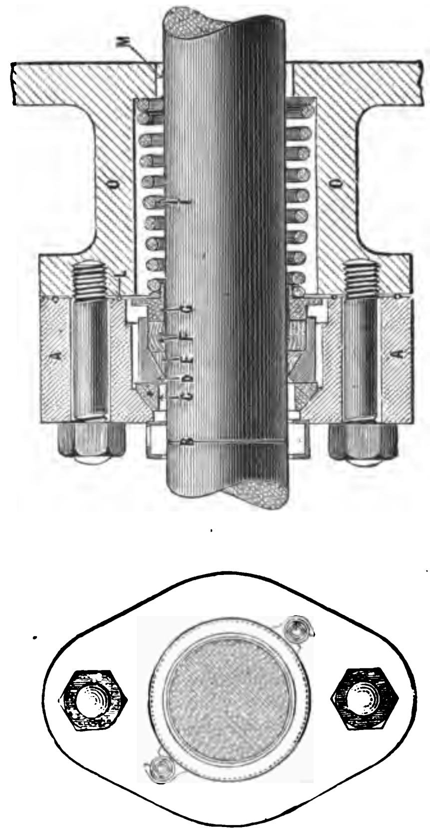
DETROIT VALVE STEM PACKING.



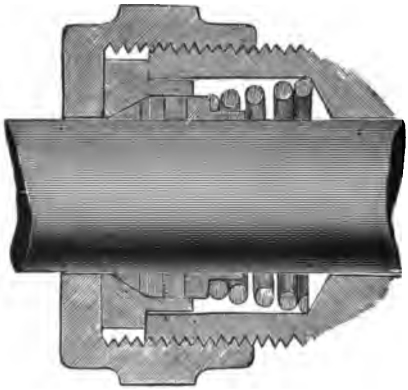
JEROME METALLIC PACKING.



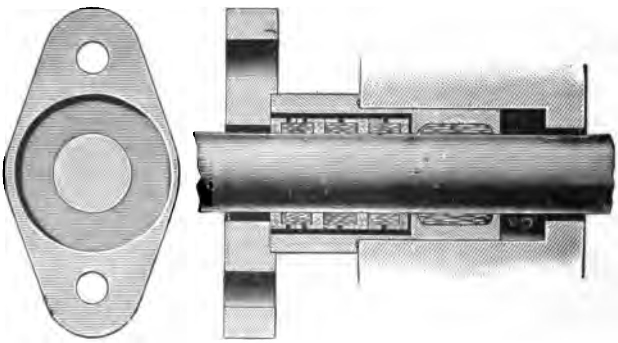
UNITED STATES VALVE STEM PACKING.



UNITED STATES PISTON ROD PACKING.



UNITED STATES AIR PUMP PACKING.



COLUMBIAN PISTON ROD PACKING.

piston rods, valve stems, air pump pistons and brake cylinder pistons. As there are so many different kinds of metallic packing in use and each claims to be the best, we have simply illustrated the different kinds in general use and shown their method of application.

CAST STEEL PISTON HEADS.

Cast steel piston heads are also in use in low pressure cylinders upon many compound engines.

A MALLEABLE IRON PISTON HEAD.

An experiment has been made on the S. C. & G. R. R. with a malleable iron piston head. The head is in two sections riveted together, and has two ordinary cylinder packing rings, the advantage being in a reduction of weight. It weighs about one-third less than the ordinary cast iron head with follower plate, and is giving very good results.

NOZZLE, STEAM PIPES, THROTTLE, ETC.

DIAMETER OF EXHAUST NOZZLES.

Owing to the changing conditions under which a locomotive must perform its work, no definite proportion can be given for the diameter of a nozzle that would give the best results under all circumstances. However, the nozzle used should be just small enough to furnish the required draft, and should be left as large as possible to reduce the back pressure in the cylinders.

It is not necessary that a single nozzle should contain twice the area of a double nozzle, as the exhaust from each cylinder is not simultaneous; yet they occur in such rapid succession that if a single nozzle was made no larger than a double nozzle, it would produce an enormous back pressure in the cylinders, and choke the engine.

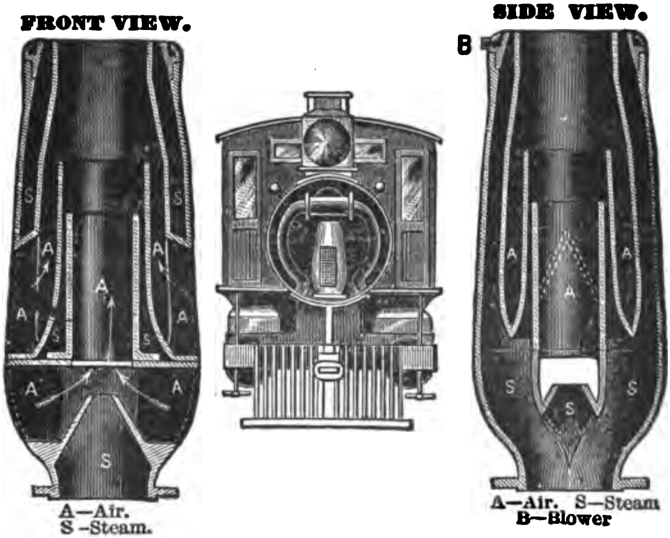
Each engine is usually supplied with three nozzle tips. The following sizes have been found to give good results with cylinders 18x24: Single nozzle, 4½", 4⅝", 4¾"; double nozzle, 3¼", 3⅜", 3½".

With 19x24 cylinders: Single nozzle, 4½", 4¾"x5". Double nozzle: 3⅝x3½x3⅝"; and other sizes in proportion to the cylinders.

THE SMITH TRIPLE EXPANSION EXHAUST PIPE.

This device is the invention of Mr. John Y. Smith, the originator of the Smith Vacuum brake. In the cuts of the front and side views shown A A represent air passages, S S exhaust steam passages, and B an annular blower, forming part of the nozzle. This is an entirely new departure in the construction of exhaust pipes for locomotives. Its distinguishing features are that the exhaust steam is not restricted after it leaves the cylinders, and the gases and heated air in the smoke arch are mingled with the exhaust in the exhaust pipe. The exhaust steam is thus super-heated and expanded, and a powerful, prolonged, pulsating blast is created, which keeps the fuel in a

constant state of agitation, and produces moru perfect combustion. Some of the beneficial results claimed are: Reduction of back pressure to a minimum (area of nozzle being greater than the steam ports); prevention of ejection of sparks from smoke stack; almost complete absence of noise from exhaust; prevention of formation of cinders in fire box, and a large



THE SMITH TRIPLE EXPANSION EXHAUST PIPE.

saving of fuel. A reduction of back pressure in the cylinders without impairing the draft of the fire has long been an unsurmountable obstacle to designers of locomotives, but it is claimed that an engine equipped with this pipe will pull from thirty to sixty tons more than with the ordinary exhaust pipe. The pipe can be used with either straight or diamond stacks, in long or short front ends, and on locomotives burning hard or soft coal, wood or coke.

HOW TO FINISH EXHAUST NOZZLE.

Chuck in lathe, bore out and turn off to required size, making a close fit in end of nozzle box, with groove for set-screw.

HOW TO FINISH NOZZLE BOX.

If for double nozzle, put a center in each end and face off each end in lathe, making right length. If for single nozzle, clamp on boring mill, keeping bottom face square with bed, and bore out and face off end for nozzle. Reverse, keeping other end square, and face off bottom joint. Or if done in lathe, put center in bottom end and put that end toward face plate on lathe; tighten the other center against piece of iron across the other end; get it to run true and face off near end, enough for steady rest; then put on steady rest and bore out and face off top end. Reverse in lathe chuck with universal chuck, and tighten back center and face off the bottom joint.

FINISH COLLAR AND ELBOW FOR ENDS OF DRY PIPE.

The collar you can chuck in lathe; bore out end that fits over pipe, making a close driving fit.

Reverse in chuck and turn and scrape steam-tight joint for flue sheet and end for nigger-head; drill and counter-sink holes all around body to rivet onto dry pipe. Chuck the elbow in lathe, or clamp in boring mill, and bore out end for dry pipe same as collar; then make joint for stand pipe and drill holes in it the same as in the collar. Now drive both ends onto pipe and scribe holes and have holes drilled in pipe; then rivet with copper rivets and calk steam-tight.

FINISH NIGGER-HEAD.

Clamp single end down on bed of boring mill; face off collar; use large round nose tool and make steam-tight joint. Reverse and finish the other side the same way.

Now clamp flatways on bed and finish the back end the same way. Drill holes in flanges and you have finished.

BORE OUT THROTTLE BOX.

Clamp on boring mill, set parallel with boring bar and turn joint on bottom end. Now reverse on bed; keep true with boring bar, set central with rough holes for throttle valve; bore out top and bottom to right sizes and face off top. Now use half-round or bevel tool in boring bar and make both seats for valve, making the top one the largest. If you have a templet make it to it.

TURN UP AND FIT THROTTLE VALVE.

A hole is usually cast through valve. Drive a mandrel through hole, or use lathe centers and face off each end. Turn wings and flanges on each end down to fit throttle box, making 1-32" loose.

Find the exact distance between the two seats in throttle box and make seats on valve, trying with black lead until you get good bearing on each seat. If you have a templet make to it.

BALANCED THROTTLE VALVES.

Balanced throttle valves have been in use on engines of the Chicago & Grand Trunk Ry. for the past four years. The valve has but one seat, which is at the top of the throttle box, and its diameter is equal to the inside diameter of the dry pipe; its connections are the same as for other throttle valves. It is claimed less power is required to operate these valves and the liability to wet steam is diminished. They are known as the Pendry Valves.

HOW TO LAY OFF STEAM PIPES.

See that nigger-head is securely fastened. Haul pipe up into place with small block and tackle; fasten temporary, putting thin board between top of pipe and nigger-head (thickness you want the top ring). Now block up the bottom so top will divide central both ways with nigger-head, and keep the bottom in proper position.

Measure the thickness each ring should be. Now use hermaphrodites and carry a line around top and bottom, true with flange on nigger-head, and face on cylinder joint below. Make the line the right distance from each face. By that we mean the thickness of each ring.

FACE OFF STEAM PIPES.

Clamp on boring mill, setting to lines on each end of pipe, and face down to the line on each end, keeping each joint perfectly square across face.

TURN BRASS STEAM PIPE RINGS.

Chuck in lathe, face flat joint perfectly true across face, and bore out. Reverse in lathe, face down to right thickness and

finish bald joint. Mark each ring where it goes. Use a scraper on joints.

GRIND DRY PIPE.

Use block and tackle; raise back end and grind front end onto nigger-head. Grind the throttle box onto dry pipe the same way.

Put pipe into boiler, clamp brace across front end, set a ratchet or screw against end of pipe, and grind to flue sheet.

HOW TO GRIND ALL JOINTS, PUT UP STEAM PIPES AND NOZZLE BOX.

Use No. 1 emery on all "brass to iron joints," and No. 2 emery on all "iron joints"; grind well until you have at least ¼" bearing on the worst place. Put the pipes up the same as for laying off pipes; put varnish or oil on all joints before tightening, and put thin copper gasket under nozzle box.

When preparing to grind steam pipe rings or other steam-tight joints, if joint looks very bad always face them off in lathe or scrape them, before grinding; then use a brace to grind with, similar to a carpenter's brace and bit.

PUT IN THROTTLE BOX AND CONNECT THROTTLE ROD.

Use block and tackle; let it down into the dome; fasten solid to dry pipe with key bolts and strap, or flanges with bolts and nuts. Keep the top of it level; then fasten to dome and put in throttle. Jam the nuts on the rod that goes through throttle valve so valve will turn around. Now connect with rod that extends through boiler head. Split all cotter pins inside of boiler; then pack throttle rod at boiler head and tighten gland.

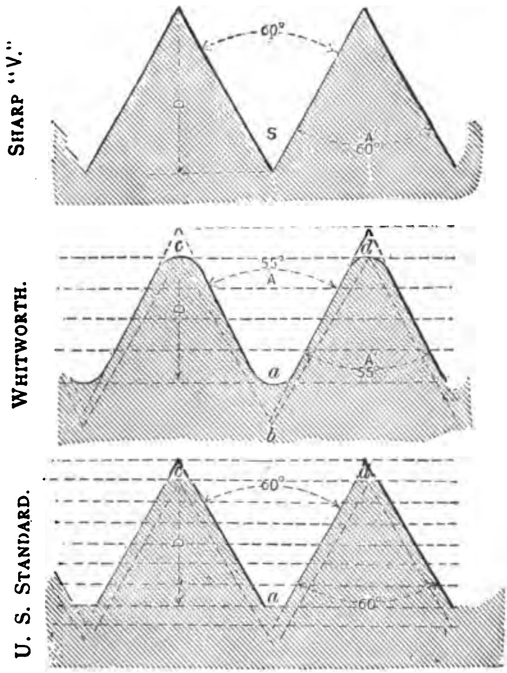
NOZZLE REAMERS.

Quite a number of different kinds of reamers are in use for cleaning out exhaust nozzles while in position in the smoke box. They are long and are used through the stack.

LATHE WORK.

UNITED STATES STANDARD SCREW THREADS.

The accompanying sketch shows the three forms of screw threads now in use in this country. The United States standard form has been adopted by the United States Government,



the Master Mechanics' and Master Car Builders' Association; Locomotive Works, Machine Bolt Makers, and many manufacturing establishments throughout the country, and is recommended by the Franklin Institute of Philadelphia. The

thread has an angle of 60 degrees with flat top and bottom,equal to one-eighth of the pitch. The advantages of this form of thread over the sharp V are that in the tap the edges of the thread are less liable to accidental injury, and will wear and retain their size and form longer, and in the bolt the flat top and bottom give increased strength and an improved appearance.

Gearing and Thread Cutting.

Simple Geared.—Multiply the number of threads (per inch) you desire to cut by any small number, and put that gear on your screw; then multiply the number of threads (per inch) on your screw by the same number and place that gear on the spindle. For example: We will use number 4, although any small number will answer the same; say you wished to cut 10 threads, multiply 10 by 4, which equals 40; put 40 on your screw. Now multiply the number of threads (per inch) on your screw (we will presume it is 6) by 4, which equals 24; and put 24 on the spindle.

Another way is to take any small gear you may have (put it on the spindle) and multiply it by the number of threads desired, and divide the product by the number of threads on your screw (per inch) and put it on the screw. If you haven't those two gears try another one, and so on until you have two that will cut it.

Many small lathes have a stud geared into the spindle, which stud only runs one-half as fast as the spindle. In finding the gears for these lathes first multiply the number of threads to be cut, as before, and then multiply the number of threads on the screw as double the number it is. For example: If you want to cut 10 threads, multiply by 4; so put 40 on the screw; then if your screw is 6, call it 12 and multiply by 4 and it will give you 48; put that on the spindle. Many of these lathes have a pin in end of spindle which changes the gear without the necessity of changing your gears; simply pull out the pin and the lathe will cut double the thread it is geared to cut.

The American Machinist gives the following rule for selecting gears to cut threads on lathes, for both single and compound gearing: If the lathe is simply geared and the stud runs at the same speed as the spindle, then select some gear for the screw, and multiply its number of threads per inch by the lead screw, and divide this result by the number of threads per inch you wish to cut. This will give you the number of teeth in the gear for the stud. If this result is a fractional

number, or a number which is not among the gears which you possess, then try some other gear for the screw. But if you prefer to select the gear for the stud first, then multiply its

LATHE TOOLS.

Left Hand Side Tool.
Right Hand Side Tool.
Right Hand Bent Tool.
Right Hand Diamond Point.
Left Hand Diamond Point.
Round Nose Tool.
Cutting off Tool.
Threading Tool.
Bent Threading Tool.
Roughing Tool.
Boring Tool.
Inside Threading Tool.

number of teeth by the number of threads per inch which you wish to cut, and divide by the number of threads per inch on the lead screw. This will give you the number of teeth for the gear on the screw.

Compound.—If the lathe is compound, select at random all the driving gears, multiply the number of their teeth together, and this product by the number of threads you wish to cut. Then select at random all the driven gears except one, multiply the number of their teeth together, and this product by the number of threads on the lead screw. Now divide the first result by the second, and you will have the number of teeth in the remaining driven gear. But if you prefer you can select at random all the driven gears. Multiply the number of their teeth together, and this product by the number of threads per inch in the lead screw. Then select at random all the driven gears except one. Multiply the number of their teeth together, and this result by the number of threads per inch of the screw you wish to cut. Divide the first result by the last, and you will have the number of teeth in the remaining driver. When the gears on the compounding stud are fast together and cannot be changed, then the driven one has usually twice as many teeth as the other, or driver; in which case you can, in the calculations, consider the lead screw to have twice as many threads per inch as it actually has, and then ignore the compounding entirely. Some lathes are so constructed that the stud on which the first driver is placed revolves only half as fast as the spindle. You can ignore this in the calculations by doubling the number of threads of the lead screw. If both the last conditions are present you can ignore them in the calculations by multiplying the number of threads per inch in the lead screw by four. If the thread to be cut is a fractional one, or if the pitch of the lead screw is fractional, or if both are fractional, then reduce the fractions to a common denominator, and use the numerators of these fractions as if they equalled the pitch of the screw to be cut, and of the lead screw respectively. Then use that part of the rule given above which applies to the lathe in question. For instance, suppose it is desired to cut a thread of 25-32 inch pitch, and the lead screw has 4 threads per inch. Then the pitch of the lead screw will be ¼ inch, which is equal to 8-32 inch. We now have two fractions, 25-32 and 8-32, and the two serews will be in the ratio of 25 to 8, and the gears can be figured by the rule above, assuming the number of threads to be cut to be 8 per inch, and those on the lead screw to be 25 per inch. But this latter number may be further modified by conditions named above, such as a reduced speed of the stud, or fixed compound gears. In the instance given if the lead screw had been 2½ threads per inch, then its pitch being 4-10 inch we have the fractions of 4-10 and 25-32, which, reduced to a common denominator, are 64-160 and 125-160, and the gears will be the

same as if the lead screw had 125 threads per inch, and the screw to be cut 64 threads per inch.

When cutting iron, keep the point or cutting edge of your tool slightly above the center. When cutting brass set it slightly below the center; for inside threads just the reverse.

SCREW OR V-SHAPED THREADS.

When cutting V-shaped threads, set your tool at right angle with lathe centers, and look at thread carefully on both sides, and see that threads do not lean like fish scales. Always grind your tool to a gauge.

SQUARE THREADS.

When cutting square threads it is always necessary to get the depth required with a tool somewhat thinner than one-half the pitch of the thread. After doing this dress another tool exactly one-half the pitch of the tread and use it to finish with, cutting a slight chip on each side of the groove. Then polish with a pine stick and emery. Square threads for strength should be cut one-half the depth of their pitch, while square threads for wear should be cut three-fourths the depth of their pitch.

MONGREL THREADS.

Mongrel, or half V and half square threads, are usually made for great wear, and should be cut the full depth of their pitch, or even more. They are sometimes cut one and one-half the depth of their pitch; the point and the bottom of the grooves should each be in width one-quarter the depth of their pitch.

DOUBLE THREADS.

The face plate on every lathe has at least four slots in it which carry the dog; so after you have cut one thread change your dog to slot directly opposite on face plate.

LEFT-HAND THREADS.

Gear up the lathe the same as for a right-hand thread, and then change the shifter on the end of your lathe. If your lathe has no shifter, put in an extra gear, so as to move the carriage from left to right. Then begin to cut the thread at the left hand and cut to right. The same way for inside or outside threads.

Turning.

DIFFICULT CHUCKING.

To chuck an odd shaped piece of work neatly and securely often requires much deliberation, considerable skill and me-

IMPROVED LATHE TOOLS.

chanical ingenuity, and is next in importance to being able to make a good fit, and an observant foreman can easily tell an experienced lathe hand by the manner he performs this kind

of work. When a job of this kind is brought to your lathe you should immediately begin to plan the best and simplest way to chuck the particular piece of work in order to keep all its finished faces (if it has any) perfectly true, and in a manner not to interfere with your tool or tool post. When possible complete all plans in your mind before you begin the job. If by placing the chuck or face plate on the bench until you get it set would be an advantage, do so; if the dogs of your chuck are too short, perhaps you may be able to clamp it to a face plate, or a short tool placed from one dog to another may assist you, or perhaps the use of a nut against one or more of the dogs, or V blocks, or a pipe center, brace or steady rest, might help you, or a block of wood cut out the proper shape may be better. It would be impossible to enumerate the many jobs of this kind, such as goose necks, injectors, etc.; meditate a little and you will most likely think of a good way.

HOW TO SET CALIPERS FOR FITTING.

Some men do all their fitting with the inside calipers, but the best mechanical way is to set the inside calipers to the exact size of the hole, then set the outside calipers to the exact size of the insides, and make all fits with the outside calipers, letting them drag over the work while in the lathe. Experience will teach the amount of drag to allow for different pressures suitable to the stiffness of your own calipers. No book can teach you how to make a fit; experience alone can do this, as it is all done by the sense of feeling, yet many valuable points may be obtained by the recorded experience of other men. With an ordinary pair of 6″ calipers 1-18″ thick, a 5-16 drag of the outside calipers will give a 30-ton fit, while a ⅝″ drag will give a 70-ton fit; much of course will depend upon the softness or otherwise of the metal and the length of the fit. The amounts above mentioned are suitable for crank pins and driving axles. Expansion must be considered when fitting bushings, and bolts should be made as near the exact size of the hole as possible.

HOW TO FIT BUSHINGS.

You must use judgment in doing this work; if your bushing is very heavy fit almost as you would anything solid, for the harding process will make it a little larger; but if a light

bushing allow about 1-64" on a 2" one, and 1-32" on a 4" bush and bore out that much larger to allow for closing. A cylinder bushing make the same size as hole or a shade smaller, owing to so much bearing.

TO FIT ALL KINDS OF BOLTS.

First, measure the distance through your hole, allow for nuts, thimble point, etc., and cut off right length under heads. Put in new centers, turn up the end for thread 1-64" under size of tap (to avoid the sharp edge on the thread) and allow plenty of draw. Then cut threads in lathe or have it done in bolt cutter. Now set your calipers to the exact size of the hole, and if an ordinary 1" bolt 6" long, make as near the exact size as possible. The smaller the bolt and the less the bearing, the tighter you can drive it in, and the larger the bolt, and the more bearing, the less you must allow for fitting and driving in.

Always use a little judgment; don't drive a bolt very tight in a light casting or you may crack it.

TAPER BOLTS.

Get the size of the hole at each end, and turn to the required size at each end. Then move back head toward you and use scale between your tool and the finished size of the bolt at each end; when your scale shows the same at each end, tighten back head and turn the bolt down to that size. Boys, learn to use your calipers, don't be afraid of spoiling a bolt. Remember you are not paid a journeyman's pay.

HOW TO SET TOOLS IN LATHE.

For Iron.—Set your tool above the center for outside turning and below the center for boring out.

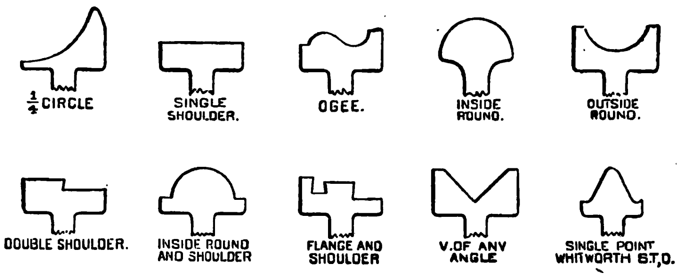
For Brass.—Set your tool below the center for outside turning, and above the center for boring out.

FINISH BRASS WORK THAT CANNOT BE TURNED.

A strop is used over two pulleys, put glue and emery on strop and hold the work against it.

GRINDING TOOLS.

When grinding machine tools always give the cutting edge sufficient clearance and angle the top face to a degree just sufficient to insure a good clean cut, so as to prevent the tool tearing, which would leave a very rough finish.



The Metric System of Weights and Measures.

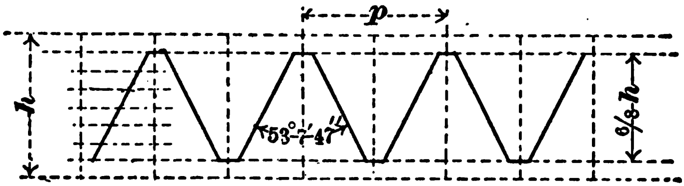
For many years the advocates of metric system of weights and measures have been laboring unceasingly to have the United States Government adopt this system and make it the only legal one in this country. As this is a subject of vital importance to every manufacturer and railroad company, and very interesting to mechanics we will endeavor to briefly explain what is meant by the metric system. This system of weights and measures was designed to remove the confusion arising out of the excessive diversity of weights and measures prevailing throughout the world, by substituting in place of the arbitrary and inconsistent systems actually in use, a simple one constructed on scientific principles and resting upon an invariable standard. The idea for a creation of such a system originated in 1790 with Prince Talleyrand, then Bishop of Antrin. The system itself was, however, matured by the labors of a committee of the Academy of Sciences, embracing Borda, Lagrange, Laplace, Monge and Condorcet, five of the ablest

mathematicians of Europe. The system has been successfully adopted by more than half the civilized world, which includes the following countries: Holland, Belgium, Spain, Portugal, Italy, the German Empire, Greece, Roumania, British India, Mexico, New Grenada, Ecuador, Peru, Brazil, Uruguay, The Argentine Confederation, and Chili. Switzerland, without adopting the system in full, has given to all her standards metric values, and Denmark has done the same for her standards of weights. Austria has adopted the system for custom house purposes; and Turkey has introduced a metric measure of length. In Great Britain the use of metric denominations in business transactions has been made legally permissible, and now a committee of the House of Commons has recommended that within two years the metric system of weights and measures shall be rendered compulsory in the British Isles. In the United States metric weights and measures were legalized by an act of Congress passed July 27, 1866, and now the House Committee on coinage and weights and measures has recommended that the metric system be adopted by the various departments of the government July 1, 1898, and by the Nation at large January 1, 1901. It is therefore fair to presume that within a few years this system will be the only legal one used in this country; so it will be well for every mechanic to study and familiarize himself with the table of metric threads shown on page 177, which were adopted by the German Engineers; we do not think a better table could be given:

A French meter equals 39.37 inches in length.
A decimeter equals 3.937 inches in length.
A centimeter equals 0.3937 inches in length.
A millimeter equals 0.03937 inches in length.

We would no doubt profit by adopting this system of weights and measures (measures of capacity) as much confusion exists, the various States having different standards, while the metric system measures of capacity, divides by tenths like its linear measurement. There are also objections to our linear measurement because it does not divide evenly like the metric system. For example, our rod contains 16½ feet and our mile 5,280 feet. But no confusion exists in our linear measurements, and when the effort is made to substitute the French meter for our inch the difficulties in the way of carrying out the change will become apparent. No objections exist to the meter as a unit of measurement, except that the parts of our existing system cannot be represented in divisions of the meter without the use of numerous figures, which would cause endless confusion. Our standards have been built up and

adopted by Railroads and Manufacturers at a cost of millions of dollars. Perhaps the most important and expensive are our screw thread, and it would be almost impossible to express the number of our threads to any part of the meter without changing the pitch of the threads, which would entail an enormous expense. Manufacturers who have a large foreign trade might profit by the change, but an overwhelming majority of the manufacturers and railroads would be forced into an unnecessary expense. The most enthusiastic advocates of this system in this country are theorists, who do not realize at what cost a change of measurement could be effected; however, their efforts have been remarkably successful and the change seems inevitable. Machines are now manufactured and used in this country which are geared to cut both United States standard and Metric threads.



$h = p$

METRIC THREADS.

TABLE OF METRIC THREADS.

Diameter of Screw. mm.	Pitch. mm.	Diameter of Screw. mm.	Pitch. mm.
1.	0.25	8.	1.2
1.2	0.25	9.	1.3
1.4	0.3	10.	1.4
1.7	0.35	12.	1.6
2.	0.4	14.	1.8
2.3	0.4	16.	2.
2.6	0.45	18.	2.2
3.	0.5	20.	2.4
3.5	0.6	22.	2.8
4.	0.7	24.	2.8
4.5	0.75	26.	3.2
5.	0.8	28.	3.2
5.5	0.9	30.	3.6
6.	1.	32.	3.6
7.	1.1	36.	4.
		40.	4.4

INJECTORS AND CHECKS.

INJECTORS.

Injectors are classed among the great improvements upon the locomotive of recent years. Every railroad man of fifteen or twenty years experience can recall the time when it was necessary to run an engine up and down the road a mile or two to "pump her up" as it was called, before the engine could start out with a train, which was a loss of much valuable time. In those days locomotive boilers were supplied with water by means of a pump, the plungers of which were attached to the cross-head; but the injector has gradually replaced the old style pump until at present very few of them are in use; a few roads still retain them on one side of their engines, but they are so few that a great many engineers of the younger generation have never seen a locomotive pump.

INVENTION OF THE INJECTOR.

To Henri Jacques Giffard, is due the honor of having invented the most simple apparatus for feeding boilers that has ever been devised, utilizing in a novel and ingenious way the latent power of a discharging jet of steam. His invention was patented May 8th, 1858, which he named an injector. His early technical education and wonderful ingenuity well fitted him for breaking away from the old beaten paths in his experiments and the method by which he proposed to force a continuous stream of water into a boiler was based upon purely theoretical grounds. Giffard seems to have considered the various phrases of the question, for there have been few other inventions in which the underlying principles have been so thoroughly worked out by the original inventor. He designed the body of the injector and proportioned the nozzles almost as they are used to-day, and the first instrument constructed entirely fulfilled the expectation of the designer. In common with all new inventions and radical improvements, considerable difficulty was at first experienced in obtaining a fair trial of its merits; the public believing the inventor was encroaching dangerously near perpetual motion, however, the Academy

of Science, of Paris, France, unsolicited, awarded to Giffard the grand mechanical prize for 1859. During the same year the injector was introduced into England by Sharp, Stewart & Co., the American patents were given to William Sellers & Co. of Philadelphia, Pa., who commenced their manufacture in 1860.

PRINCIPLE OF THE INJECTOR'S ACTION.

While the principle of the injector's action is thoroughly understood by scientists, a wide difference of opinion has always existed on this subject among railway employes, but in this age of literature it is gradually becoming more clearly understood. The principle of the injector's action is that of induced currents. Under a given pressure the velocity of escaping steam is much greater than that of the water. For example, if a boiler with 90 lbs. pressure had two holes cut in it simultaneously, one above and one below the water line, the velocity of the escaping steam would be about nine times greater than that of the water. Water being a solidity will not penetrate the atmosphere as rapidly as steam, which is only a vapor, and the principle is now well known that a current of any kind has a tendency to induce a movement in the same direction of any body it passes or touches; thus, a rapidly passing train will draw articles in its path, for the same reason wind will cause a riffle or produce waves when passing over a body of water. Therefore the steam which has the greatest velocity meeting the water in the injector induces its movement, and the water which is a solidity strikes the check valve with sufficient force to raise the valve, and its momentum keeps the check valve open, but the temperature of the steam is greatly reduced before re-entering the boiler. Injectors do not always begin working when the throttle is first opened, for that reason an overflow is supplied where the water can escape until the required momentum is attained. Blowers, steam siphons, steam jets and many other instruments are operated upon the same principle.

CARE OF INJECTOR.

Many a fire has been killed and many an engine towed in owing to the Engineer's lack of knowledge of the injector. Every man who is intrusted with the care of an injector should thoroughly understand its philosophy; if he does not he cannot expect to operate it successfully at all times, for, like the valve motion of a locomotive, a familiarity with its use does not teach the principle of its action. It is true, the difficulties

connected with the successful operation of the injector have been materially lessened by the use of the improved injectors that are now in use; nevertheless, every prudent engineer or thoughtful machinist makes it an object of ambition to study the principle of the injector's action and its construction, in order to enable him to locate any defect in its action. To preserve a good working injector all pipes and joints should be kept perfectly tight, and all stems well packed, as the admission of air into the injector will affect its action. The air mixing with the water has a tendency to decrease the speed of the water, by impairing its solidity and making it a semi-elastic body; such a defect can usually be detected by a bubbling sound at the check valve, the water not being a solid compact body. Small leaks neglected will eventually cause the injector to break, or not work at all. All pipes leading to the injector should be carefully examined for leaks, particularly the feed pipe above the water level. Leaks affect lifting injectors most, as it prevents the steam jet from forming a vacuum. The object of the steam jet (or primer) on all lifting injectors is to force all the air out of the injector. The atmospheric pressure on the water in the tank then forces the water up the feed pipe and into the injector, when the steam can be turned on full force. Most improved injectors have a small priming valve attached to the steam ram, so the injector must be primed before the steam valve can be fully opened.

When an injector will not prime, first, see that you have a sufficient supply of water in the tank, and if in the winter, see that the tank is not froze up to prevent the admission of air. Next see that the overflow or hose is not stopped up, or that the check is not stuck, when a check leaks or sediment gets on the seat it sometimes prevents priming. Give the check or branch pipe one or two slight taps and it may start, but don't batter it out of shape. If you have a bad check, report it. If the injector sucks air, or if the nozzles are out of line, it will not prime. If it primes all right, but breaks, it indicates that the check valve is stuck, or the injector is sucking air, or that it is not receiving sufficient water. Examine your hose; if it is all right, disconnect branch pipe from check and clean it out, or it may be in the nozzle. If it primes but won't start, and steam and water both escape at the overflow, increase the steam pressure, or reduce the supply of water. (The steam throttle at the boiler should be once regulated and then marked some way to avoid further trouble with it.) In this case the check valve may not have sufficient lift. Some injectors have an adjustable combining tube which adjusts itself to the volume of steam and water passing through it; if this tube is prevented from working freely, by either grit or sand, the

injector will break. Clean out the hose frequently, for cinders and dirt choke up the strainer very quickly. A frequent cause of annoyance with injectors is a leaky check valve which blows back and heats the injector so that it will not work. In such a case open the water valve and overflow and turn the primer full on and try to fill the injector with cold water, letting it run a few minutes, when the injector will probably start. Such a check should be reported at the first opportunity. Perhaps the most frequent cause of the injector refusing to work is in calcareous districts where it becomes choked with lime. This is easily discovered, as its force will gradually diminish until it refuses to operate at all, but it will have a tendency to work under low pressure. Another defect is a loose nozzle, which will work best with a high pressure of steam; this may be discovered by removing the frost plug and the main ram. When nozzles are worn too large the injector will refuse to work, and they should be replaced with new ones. In winter all injector pipes should be supplied with drain cocks at their lowest point, and kept open when not in use to prevent the pipes from freezing. Injectors should be oiled regularly, but lard oil should not be used, as it has a tendency to make the water in the boiler foam. When this occurs change the water in the boiler and tank at the first opportunity.

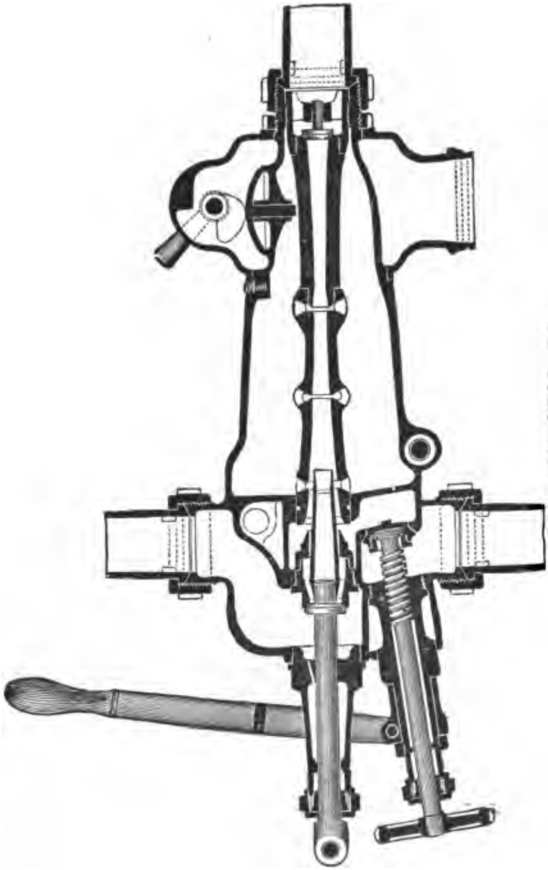
DIFFERENT FORMS OF INJECTORS.

Since the advent of the injector into this country, a great variety of these instruments known as injectors and inspirators have been introduced, but all of them conform to the same elementary principle in their mode of action, which we have already explained. The difference in their construction being to regulate the capacity and extend their action under varied conditions, such as different pressures, lifting water above its natural level, and working automatically. Very few inspirators are now in use upon locomotives, the improved injectors being considered best adapted and more reliable for road service, and as they all operate upon the same principle we have only illustrated a few of those which are most extensively used, and explained how they are operated.

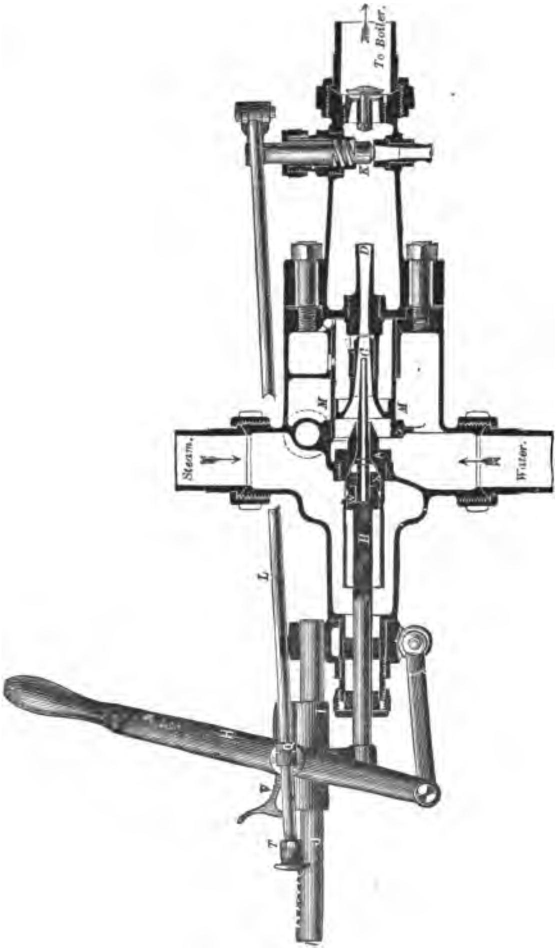
SELLERS' INJECTORS.

The first two cuts show Sellers' latest improved No. 10½ restarting injectors; that is, if the water is temporarily interrupted the injector will start again automatically as soon as the supply is resumed. It is self-adjusting, requiring no regu-

SELLERS' IMPROVED INJECTOR OF 1893.



SELLERS' INJECTOR OF 1887.



SELLERS' NO. 6 INJECTOR OF 1876.

lation of the water supply to prevent overflow above 40 lbs. steam pressure, and its construction is such that the tubes and other parts can be easily taken out for cleaning and repairs. In the 1893 injector the water supply valve has been altered and a graduated lever and index substituted for the regulating hand wheel, the tubes and nozzles remaining unaltered.

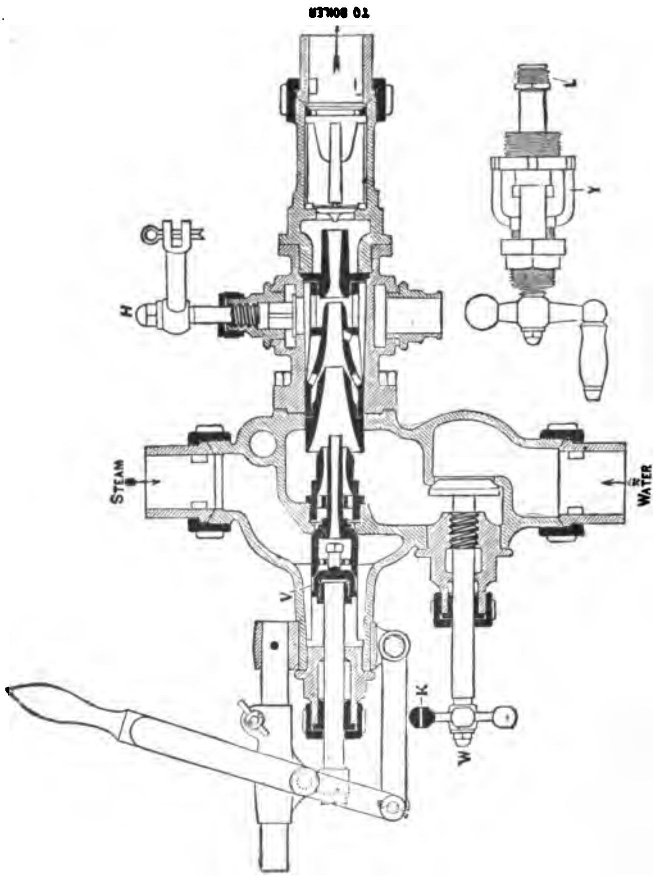
HOW TO OPERATE.

To Start—Pull out the lever. To Stop—Push in the lever. Regulate for quantity with the water valve. To use as a heater, close the waste valve and draw the starting lever. When the water flows to the injector it is of course necessary to open the water valve before pulling out the lever, and to close it after pushing in the lever. In starting on high lifts and in lifting hot water, it is best to pull out the lever slowly.

As there are a great many of the old No. 6 injectors of 1876 still in use, we have shown an interior view of one of them. This is a self-adjusting injector, during its time it was adopted as a standard by the Pennsylvania Ry. Co., but it is too small to supply the large locomotive boilers in use at the present day. Right here it may be well to state the significance of numbers on injectors, which means the exact diameter of the smallest orifice of the delivery tube, expressed in millimeters, which is equal to .3937 inches (see Metric Threads, page 174). All the tubes of the Sellers injectors are connected together, and when not corroded are easily removed all together through the delivery end. To operate the 1876 injector all that is required is the movement of the lever.

MONITOR INJECTORS.

Since the introduction of the Monitor injector in 1880 they have been classed among the most efficient and reliable injectors in use, and they are so extensively used in this country that no introduction is necessary here. The first cut shows the latest development of the Monitor, which is a No. 9 Monitor of 1888. The latest improvement in this injector is the lever handle attachment and different form of water valve which is less liable to corrosion. The independent lifting jet, by which the Monitor has long been distinguished, is here dispensed with, and a taper lifting spindle in the steam nozzle which discharges through the combining tube is substituted. These injectors will operate under very low pressure, and the body is divided into three sections, which is very convenient for repairs.



IMPROVED MONITOR INJECTOR OF 1888.

P. R. R. STANDARD MONITOR.

The next cut shows the form of Monitor of 1888 adopted as a standard by the Pennsylvania Ry. Co., the difference being in the position of the lifting jet and in the form of nozzles, the nozzles all being attached so they may be removed through the delivery end like the Sellers nozzles.

HOW TO OPERATE.

With Lever Motion.

To Start.—Pull out the lever a short distance to lift the water; when water runs from the overflow, steadily draw back the lever until overflow ceases. Do not increase the water supply after overflow has ceased. Regulate for quantity with water valve W.

To Stop: Push in the lever.

With Screw Motion.

To Start: Open the steam valve one-quarter of a turn to lift the water. When water runs from the overflow, open steam valve until overflow ceases. Do not increase the steam supply after overflow has ceased. Regulate for quantity with water-valve W.

To Stop: Close steam valve.

To Grade Injector: Throttle water by valve W; if this is not sufficient, reduce the steam by pushing in lever handle about half way and in case of the screw motion, by screwing in the steam spindle about half way.

To Use as a Heater: Close valve H and pull out lever all the way, and in case of screw motion open valve full. At all other times valve H must be kept open.

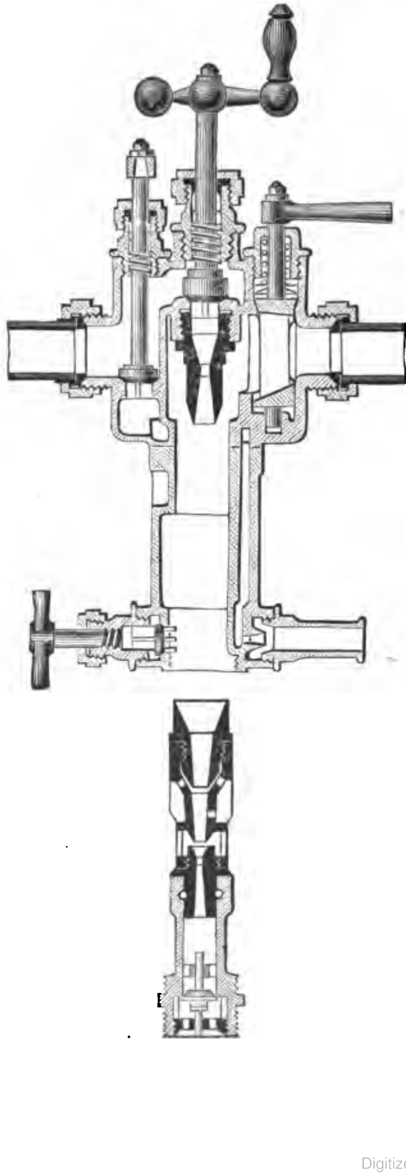
The heater cock can be worked from the cab by means of an extension rod.

The hole in the knob K of water handle W indicates the position of the water valve. One turn of the handle fully opens or entirely closes the water passage.

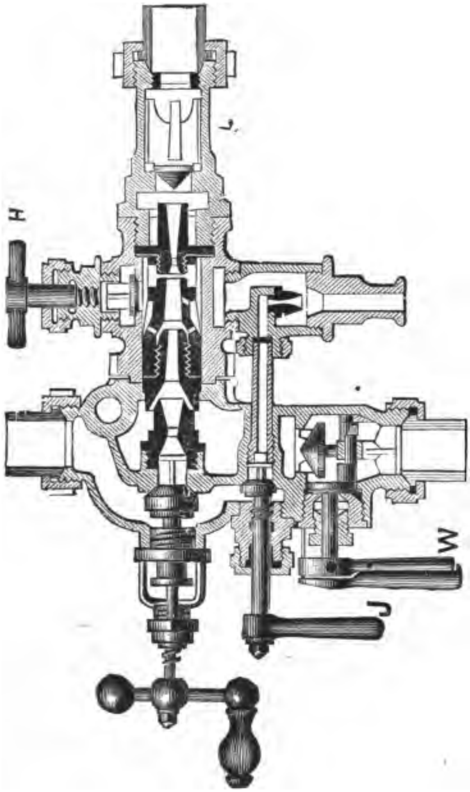
In either case, the knob with the hole in should be in an upright position. Intermediate positions of the knob K indicate corresponding openings in the water passage.

STANDARD MONITOR.

The next cut shows the Standard Monitor injector, which style is perhaps in most general use at the present time. A great point of convenience about these injectors is that they



P. R. R. STANDARD MONITOR INJECTOR.



STANDARD MONITOR INJECTOR.

can be located and operated either inside or outside the cab, and the valves are all easily removed, and the body of the injector being in two sections, the nozzles are easily taken out.

HOW TO OPERATE.

To Start: Open jet J. When water appears at overflow, open valve S until overflow ceases, then close jet J. Do not increase steam supply after overflow has ceased.

To Stop: Close valve S.

To Heat Water in Tender: Close valve H, and open valve S; but the valve H should never be closed except when the injector is to be used as a heater-cock. Regulate for quantity of water needed by valve W.

To Grade the Injector: Throttle water by valve W. If this be not sufficient, reduce the quantity of steam supplied.

A small lubricator should be attached to the oiler plug of injector to lubricate the nozzles and prevent incrustation or corrosion.

Whenever the road passes through a section of country where the water is impure or limy, the nozzles should be taken out of the injector frequently and placed over night in a bath of mineral oil, or washed in a dilution of sulphuric acid, to remove deposits from the surface.

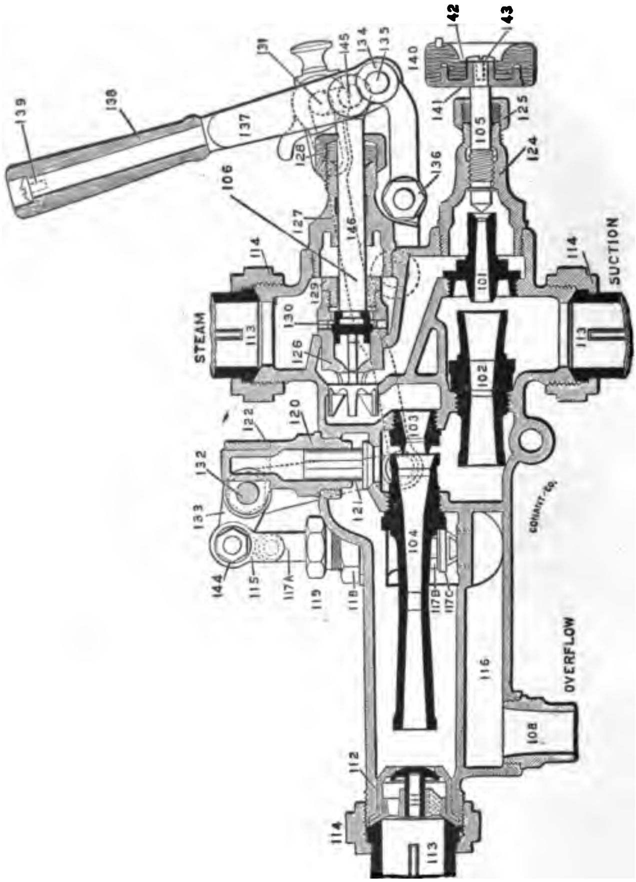
LITTLE GIANT INJECTOR.

These injectors, of which we have shown a cut of the most improved pattern, are no experiments, as they have been in service for twenty-five years. They are simple in construction, easily operated and are the only injectors made having a movable combining tube which the operator can adjust to work under different pressures of steam.

THE HANCOCK INSPIRATOR.

We have shown a sectional view of the latest Hancock locomotive inspirator of 1894, and explain its mode of action. The difference between injectors and inspirators is, that the inspirator is a double apparatus combining the lifting and forcing jets and tubes in the same instrument and operating with closed overflow, while in the injector they are independent of each other. The first Hancock inspirator was manufactured in Boston in 1874. The following is its mode of action: By a slight pull of lever No. 137, steam is admitted by valve No. 130 through main steam valve No. 126 to lifter steam nozzle No. 101, the velocity of which into No. 102 creates a vacuum, causing water to flow through No. 102, condensing the steam,

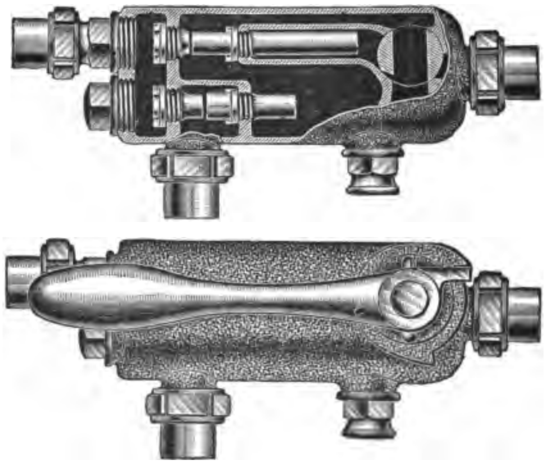
LITTLE GIANT INJECTOR.



THE HANCOCK INSPIRATOR.

and out No. 121 at the final overflow valve No. 117 in delivery chamber. By a further movement of lever No. 137 the main steam valve is opened—No. 126, and steam admitted to forcer steam nozzle No. 103, which takes the water from No. 121 through forcer combining tube No. 104, raising pressure in delivery chamber above boiler pressure, when line check valve No. 111 is opened, and the inspirator is at work; the combining operation takes about 30 seconds only to complete, from start to finish.

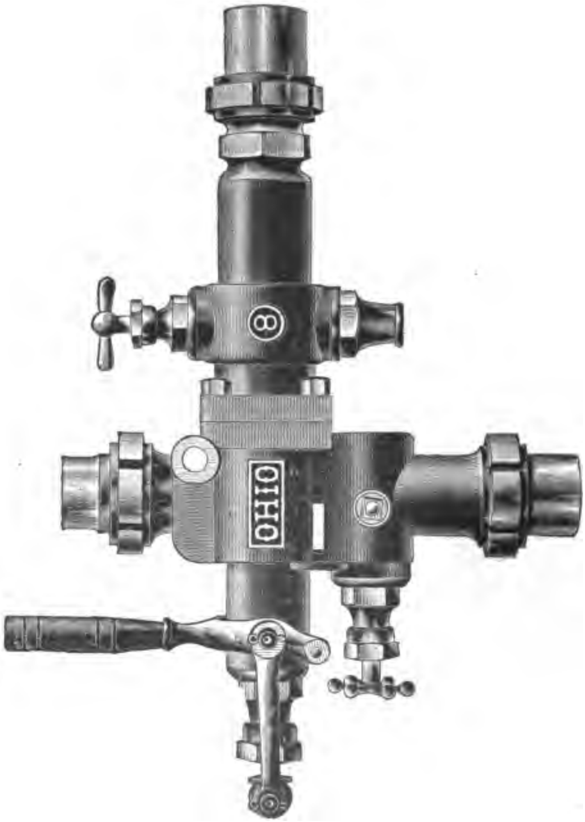
THE BROWNLEY DOUBLE TUBE INJECTOR.



We present two views of this injector, which is perhaps the most simply constructed injector made, having but one valve. It is in use on the Manhattan Road of New York, where it is said to have given better results than any other form of lifting injector, being very powerful and at the same time economical on steam. It will work under any pressure from 15 lbs. to 350 lbs. and is operated by a simple movement of the lever.

OHIO INJECTOR.

This is a thoroughly modern injector designed to meet the requirements of the present day. It is noted for its simplicity, having fewer parts than most injectors which are arranged in


8
OHIO

a convenient manner for repairs. The combining and delivery tubes are both attached to the nose of the injector so that they are easily removed and the lifting tube, instead of being screwed to the shell, is held in place by the flange joint. Quite a number of these injectors are now used.

THE GARFIELD INJECTOR.

This is another modern injector which is in use on many of our railroads. It is constructed in a most convenient form for repairs, most of the nozzles being clamped together by the flange joint, which makes them easy to remove. It is operated by a simple movement of the lever, the supply being regulated by the water valve. Like most other injectors it is claimed to be superior to all others.

REPAIRING INJECTORS.

The requirements to perform this work successfully are two; first, a thorough knowledge of the construction of the injector and check, and the principle of the injector's action, and secondly, the hand of a skilled workman to make the needed repairs. It is considered nice clean work in a machine shop, but every machinist is not competent to perform this work, and furthermore not every machinist who is allotted to this particular line of work performs it successfully. This is one of the many jobs in the machine shop which requires more than practice to thoroughly understand. Below we give the method of performing this work, but it requires much reflection and should be done carefully. When overhauling an injector of any make, take out the main valve (or ram), the primer cock, the water valve, and the frost plug, then take injector apart and take out the nozzle. Clean all dirt or sediment out of the shell and soak shell in benzine to remove scale from inside, then examine the nozzles carefully before putting back in; if they are cut bad or worn out larger than their standard size, turn up new ones. See that nozzles are firm when intact, and if the injector divides into two or three parts see that each joint is steam-tight, and when putting together use oil, white lead or varnish, and tighten firmly. Now examine all valves and seats and if they are cut bad face off valves, or replace them with new ones; then face seats, using a bushing to keep rosebit central. Now grind all valves and seats steam-tight, using flour emery. Now examine threads on ram and other stems; also, on all plugs and packing nuts, and if very loose, replace with new ones. Now put it together and make each joint steam-tight. Now re-pack all the stems with asbestos, if you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have it; if not, then use lamp wick, or some other kind of packing. Now your injector is finished. When taking an injector apart, if some parts are very tight, warm them a little and they will readily loosen. Brass expands very quickly. If an injector is reported thus: won't work; first take the cap off check, and if it is all right, examine feed pipe and hose for holes to see if the injector sucks air. If not, then take out main valve and primer cock; if they are all right, take out frost plug and see if injector is full of lime; if you cannot locate the defect in this way then take down the injector and overhaul it, as per instructions above.

INJECTOR CHECKS.

It is very essential that the boiler check should be in good working order, or the injector will not work. If the valve gets cocked, or sticks, the injector will not work. If the valve or seat leaks, and blows back sufficient steam to heat the injector, it will not work, or if the valve has not sufficient lift, the injector will not work. So you see while a check is very simple in its construction, it is very important, and should be perfect in every detail. Checks usually have three lugs cast on them for turning. Chuck the bottom lug and bore out and make seat for valve; face off joint and cut thread for cap. Put a center in each of the other lugs and run a pipe center into end of stem; cut off right length and cut thread tapering for fit in boiler or check plate. Cut thread on either stem or nut, and make seat for branch pipe; turn up cap, nut and thimble and valve. Make valve 1-32 of an inch loose sideways and give it ¼ of an inch lift. Then grind seat and valve steam-tight and you are finished. Some roads use safety checks, which are fastened on the inside of the boiler, and are very good in case of an accident.

Some roads use an extra check valve in the branch pipe to prevent heating the injector in case the boiler check leaks.

The modern, up-to-date locomotives have both injectors placed on the right side, which is more convenient for the engineer and relieves the fireman.

LUBRICATORS.

LOCOMOTIVE CYLINDER LUBRICATORS.

Cylinder and air pump lubricators are in use upon all modern engines. The object of the lubricators is to furnish a regular and constant supply of oil to the parts while working steam, which could not be accomplished before the lubricator came into use. With the old style oil plugs formerly in use, it was necessary to shut off steam pressure before the cylinders could be oiled. The lubricator overcame this difficulty and at the same time supplied a means of continuous feed which is capable of very accurate adjustment, thereby permitting of an economical use of oil. These lubricators are made in different forms, some supplying the cylinders only, others the air pump, while the latest design combines both cylinder and air pump feeds. We have illustrated only those which are mostly used. This cut is a "Nathan."

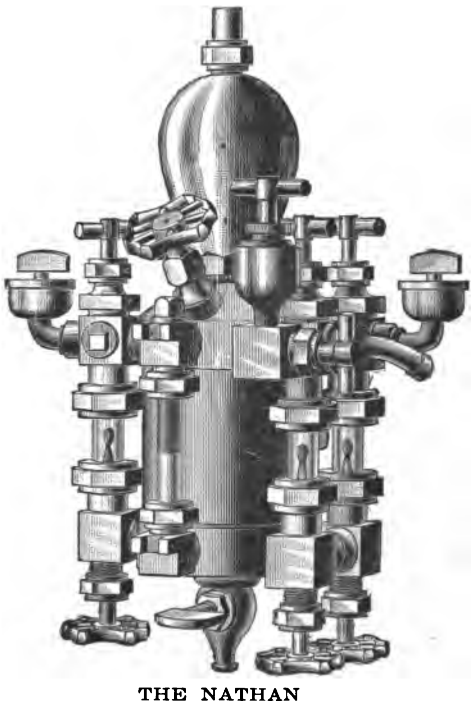
MODE OF ACTION.

In this lubricator as in all others the oil rises to the top of the water which is condensed steam, and then passes down through the pipes shown on the interior views, then out to the feed valves where the supply is regulated; it then passes up through the sight feed glasses which are filled with condensed steam, thence into the oil pipes to the cylinders and air pump. We have shown interior views of "The Detroit" lubricators with each part named and numbered so the reader may study their construction and become familiar with the correct names of the various parts. We also give instructions in regard to the attachment of the lubricator, how to fill it, operate it and how to overhaul or repair them when out of order.

HOW TO ATTACH THE LUBRICATOR.

Support lubricator with a heavy bracket (2x⅞), preferably

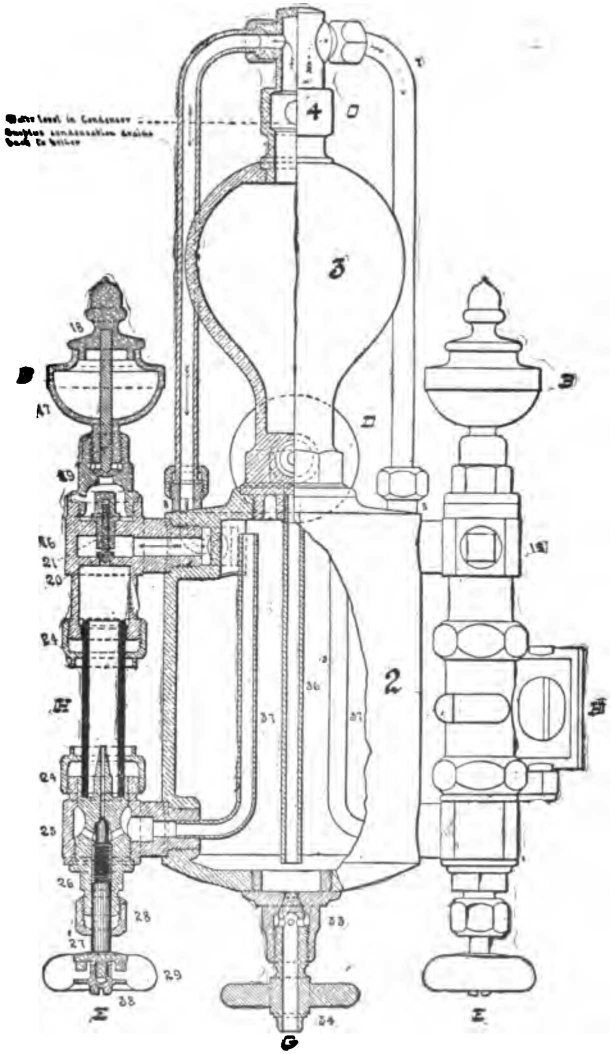
in center of boiler head. Connect with tallow pipes, which should have a marked descent to steam chests. Remove valves from over steam chests. For steam, connect at C direct with boiler, always allowing pipe to descend gradually to the boiler to permit surplus condensation to flow back to boiler.



THE NATHAN

How to Fill: Close valves D, EE and I, and fill with clean strained oil.

How to Operate: Open steam valve M one turn for boiler pressure, then valve D, regulate feed with valves EE and I. BB, auxiliary oilers, are entirely independent of the lubricator, and are to be used the same as old cab oilers, when necessary, by simply closing the engine throttle.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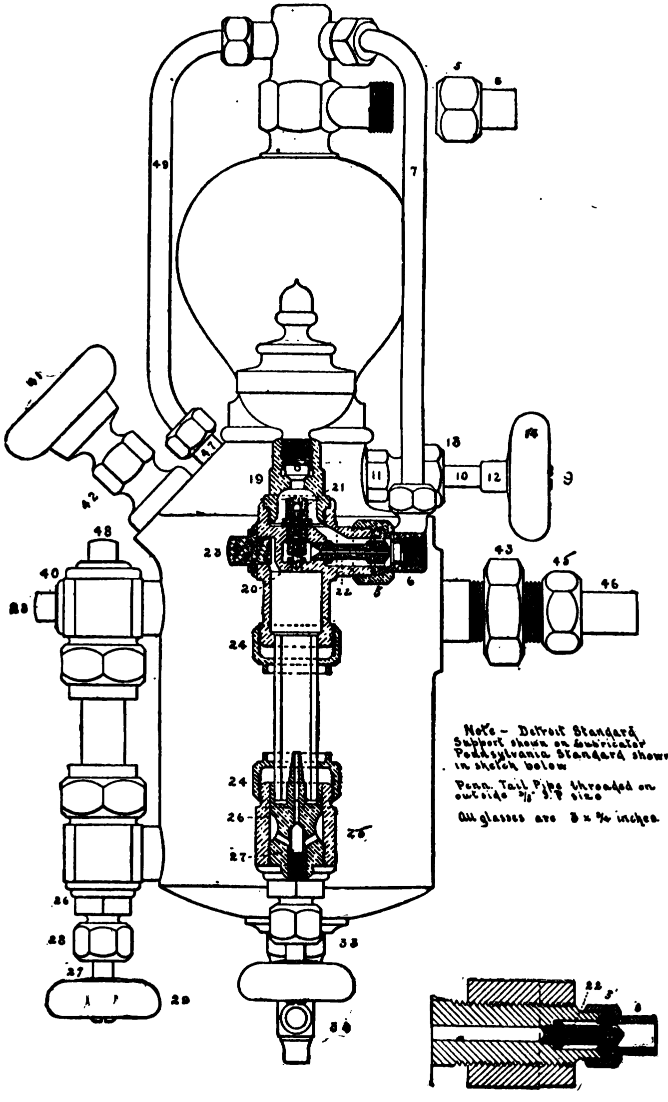
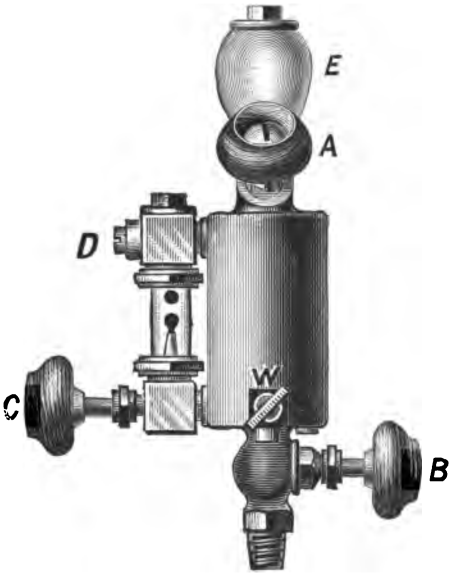

Note – Detroit Standard
Support shown on Lubricator
Pennsylvania Standard shown
in sketch below
Penn. Tail Pipe threaded on
outside 3/8" I.P size
All glasses are 3 x 5/8 inches

PARTS OF CYLINDER LUBRICATOR.

2—Oil Reservoir, quart size.
3—Condenser.
4—Extension Top Complete.
5—Tail Nut.
6—Tail Pipe.
7—Equalizing tubes.
8—Elbows.
9—Water Valve Complete.
10—Water Valve Stem.
11—Water Valve Center Piece.
12—Water Valve Follower Plate.
13—Water Valve Packing Nut.
14—Wood Handle.
15—Upper Feed Arm, right.
16—Upper Feed Arm, left.
17—Hand Oilers.
18—Hand Oiler Covers.
19—Hand Oiler Plugs.
20—Check Valves.
21—Check Valve Guides.
22—Nozzles.
23—Water Plugs.
24—Packing Nut for Glass.
25—Lower Feed Arm.
26—Feed Valve, Body.
27—Feed Valve, Stem.
28—Feed Valve, Packing Nut.
29—Feed Valve, Stem Handle.
30—Filler Arm.
31—Filler Plug.
32—Lower Gauge Arm.
33—Drain Valve Body.
34—Drain Valve Stem.
35—Jamb Nut.
36—Water Tube.
37—Oil Tube.
38—Handle Button.
All Glasses, 3x¾.

AIR PUMP LUBRICATOR.

The exterior view of the Air Pump Lubricators herewith shown is of the Nathan type and the interior view represents the Detroit pattern. These lubricators should be connected to the steam pipe leading to the brake pump.



THE NATHAN.

DIRECTIONS FOR USE.

Fill the cup with clean, strained oil, through filling plug A.

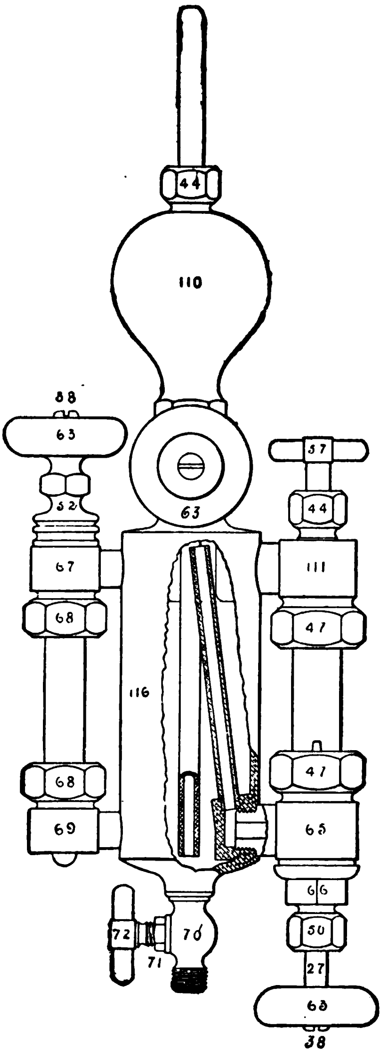
To Start: Open valve B, wait until glass has filled with condensed water, then regulate the feed by valve C.

To Stop: Close valves C and B.

To Renew Supply of Oil: Close valves C and B and draw off water at waste cock W; then fill the cup with oil and start again as before.

PARTS.

27—Feed Valve Stem.
38—Handle Buttons.
43—Globe Valve, Center Piece
44—Globe Valve, Stem Nut.
44—Equalizing Tube Nut.
44—Pulsating Stem Nut.
45—Globe Valve Stem.
47—¾ Nuts.
50—Feed Stem Nut.
52—Filler Plug.
57—Pulsating Valve Stem.
62—Globe Valve, Body.
63—Wood Handle.
65—Lower Feed Arm.
66—Feed Valve.
67—Upper Gauge Arm.
68—⅝ Nuts.
69—Lower Gauge Arm.
70—Drain Valve, Body.
71—Drain Valve, Center Piece
72—Drain Valve, Stem.
110—Condenser.
111—Upper Feed Arm.
112—Support Arm.
113—Right and Left Coupling Nut.
114—Support Post.
115—Equalizing Tube.
116—Oil Reservoir.
Gauge Glass, ⅝x3¼.
Sight-Feed Glass, ¾x3.



Note.—The valves (with the exception of filling plug) should be opened wide, and steam blown through them once in every two weeks at least, to cleanse them thoroughly.

HOW TO REPAIR LUBRICATORS.

If lubricator won't work, open the bottom cocks and turn on full head of steam and blow out. If it won't work then, take out all the glass tubes and examine small feeders and see that they are not stopped up with dirt or waste, which may have been in the oil. If they are all right, take lubricator down and screw chamber off of top and see if any of the small feed pipes inside are broke off, or stopped up; clean out good, then take out all cocks and clean them out. If threads are stripped on any of them, make new ones. Screw all of them in tight, making steam tight joints, and put up, and you will find it will work all right. If any glasses are broken, replace them and repack all nuts.

A FORCE FEED LUBRICATOR.

Another improvement which often relieves the engineer from much annoyance with hot bearings and possible delays is the Force Feed Lubricator. It is especially valuable where long runs must be made without stops.

This lubricator is placed in a convenient position in the cab and small pipes lead from it to each of the journals on the engine, also to the eccentric straps and links. Any of bearings can be oiled independently or all together. The lubricator holding one gallon of oil, either steam or air may be used to force the oil to the bearings for all main journals. Three-way tips are used for ends of the pipe, thus permitting the shoes and wedges to be oiled as well as the journals. This device has been in use about two years.

STEAM AND AIR GAUGES.

Two forms of steam gauges are in general use upon locomotives, one using a diaphragm and the other a hollow seamless brass tube in the shape of the letter C, having an elliptical

UTICA STEAM GAUGE.

section. We have shown an interior view of the three different styles of gauges, of the most improved type.

In the Utica gauge the pressure is behind the diaphragm; the face of the diphragm is corrugated and a bell crank lever

CROSBY STEAM GAUGE.

bears against its center. The interior mechanism is so arranged that the slightest pressure inside of the diaphragm will cause it to bulge out, which will affect the position of the hard or pointer.

ASHCROFT STEAM GAUGE.

In the other form of gauge like the Crosby and Ashcroft, the pressure acts on the inside of the brass tubes, which has a tendency to straighten the tubes, thus spreading the ends to which

is attached a bent lever which imparts a movement to the hand or pointer by the mechanism shown. The old style gauges of this type had but one tube, but by having the lever attached to the end of two tubes as shown by these improved gauges, the distance the lower lever moves is double what it would be if attached to only one tube.

The steam pipe which connects the gauge with the boiler should be bent in the shape of the letter S for all gauges to permit the steam to be condensed in the pipe, as the steam pressure affects the elasticity of both diaphragms and tubes.

AIR BRAKE GAUGES.

We present herewith two views of the Utica Air Brake Gauge, which is a thoroughly modern gauge. It shows the pressure on the train line pipe and at the same time the pressure in the reservoir. The improvement of this gauge over others is the double spindle. The hands are easily distinguished even at night and no large center bearing is necessary as is the case where one spindle passes through the other. The center spindle of any gauge should be very delicate, as the slightest friction at this point would impair its accuracy.

TESTING GAUGES.

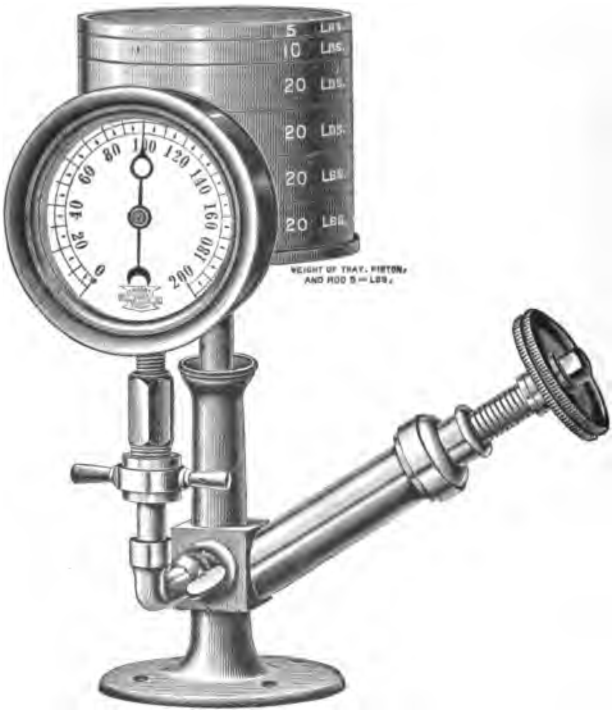
Most large shops have a hydraulic apparatus for testing gauges. In order to test a gauge intelligently the operator should understand the construction of the gauge to be tested, and the action of the pressure upon the gauge. A gauge is said to be heavy when it indicates less than the test gauge, and it is called light when it indicates more than the test gauge. A light indicating gauge is often caused by the diaphragm or tubes becoming set or extended, in which case the hand will not come back to the pin, but will indicate 10 or 12 pounds pressure when there is no pressure. By giving a light spring to the tube or diaphragm will often remedy this evil. A heavy indicating gauge may be caused by the tubes or diaphragm not moving the proper distance at which the dial was marked off at the time it was made and tested, or it may be caused by the dial moving around. In a diaphragm gauge any dirt that would get between the bell crank and diaphragm would cause a heavy gauge. Another cause of this defect is a choking up of the proper pressure opening, lost motion in the mechanism will also cause a heavy indicating gauge. See that the tubes or diaphragm do not leak, and remember the small spring is capable of adjustment. The practice of resetting the hand or pointer is a bad one, and should only be resorted to when all other remedies have failed.

UTICA AIR BRAKE GAUGE.

UTICA AIR BRAKE GAUGE.

A RELIABLE GAUGE TESTER.

This cut shows Crosby's latest improved weighted gauge tester. This is the most simple gauge tester we know of and the least liable to get out of order. The gauge shown on the cut is not a part of the device, but is the gauge being tested. As may be seen this tester consists of a cylinder with a piston

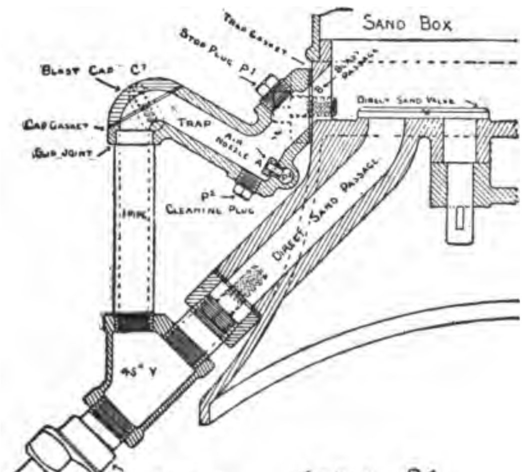


fit into it whose area is one-fifth of a square inch. The piston moves freely up and down. Attached to the top of the piston rod is a disc for supporting the weights, which are made of brass, each weight being numbered according to the pressure it will exert on the gauge. One of the tubes which projects from the cylinder is furnished with couplings to attach the gauge to be tested, the other forms a reservoir for oil, having a screw plunger for forcing the oil inward or outward.

GENERAL INFORMATION.

THE LEACH SANDER FOR LOCOMOTIVE.

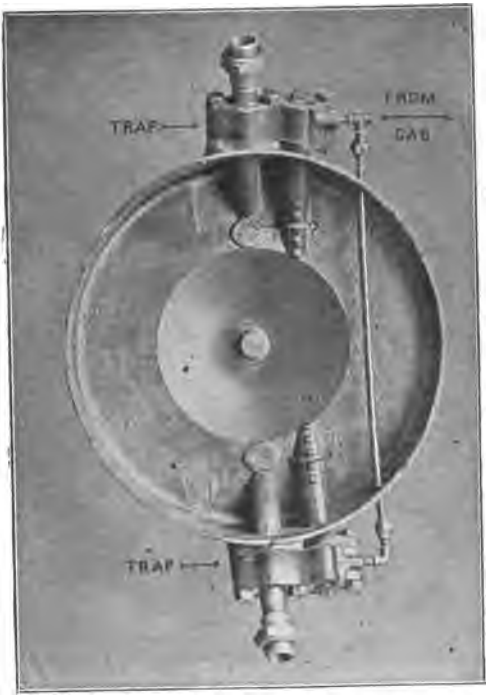
Three or four different track sanders are now in use upon locomotives, but as the Leach sander is the most extensively used, we have illustrated this particular device and explained its advantages and its method of application and operation.



STYLE B1.

This device is intended to reduce to a minimum the evils due to sanding the track for preventing the slipping of locomotive driving wheels. The ordinary sand lever arrangement is hard to operate, and is also very wasteful of sand, thereby causing unnecessary wear of tires and rails, and also resistance to trains.

A sand trap, or pocket, in which is an air nozzle, one trap being provided for each sand pipe, and attached to the outside of the sand box, that it may be readily inspected, is the main feature of the device. The trap receives its supply of sand through an auxiliary passage which is normally open, and delivers it into the sand pipe as may be required, by means of



the air blast. This arrangement does not interfere with the sand lever and valves, which are preferably retained for emergency use.

Suitable arrangements are provided in the trap for receiving the wear of the sand blast, and also for removing stones and other foreign substances.

The compressed air used is taken from the air brake pipe

which leads from the main reservoir to the engineer's brake valve, the pipe conveying this air to the sand box being placed, whenever possible, under the boiler jacket, in order to heat the air.

The feed valve which regulates the air pressure and thereby the sand delivery, is a small globe valve having a fine thread on the stem, and with the angle of the valve seat nearly parallel with the stem. This allows of very fine adjustment, as a considerable movement of the valve wheel is necessary in order to secure a perceptible opening of the valve. This fine adjustment of the feed is an important feature, as a pressure of but two to five pounds at the air nozzle is required for light feeding, and a higher pressure would result in a waste of air and sand, which must be avoided.

In order to prevent the feed valve being forgotten and thereby left open longer than needed, a tell-tale attachment is provided in the valve wheel, which sounds a warning whenever the valve is opened for sanding, unless prevented by the pressure of the operator's hand. If the hand is removed for other duties, the feed continues, but the warning sounds until the hand is replaced, or the valve closed.

The first cut illustrates the principle of the device, but this form is only occasionally used. The style in most common use is shown in the second cut, which represents an inverted sand box base with the sand traps and pipes attached, but with the sand lever and valves removed. For new work, the auxiliary passages are cast instead of bolted in.

Double traps, designed for two pairs of sand pipes on the same sand box, are made and applied in a similar manner.


Chime Whistle.

CHIME WHISTLES.

The peculiar merit of this whistle consists in producing three distinct tones pitched to the first, third and fifth of the common musical scale, which harmonize and give an agreeable musical chord. It is more penetrating than the common whistle, and can be heard at a greater distance. It effectually obviates the harsh, disagreeable noise which has been a source of common complaint in other whistles. This

whistle is used extensively on locomotives, and is warmly indorsed by railroad men and by the traveling public. They overcome one of the chief annoyances of railway travel, and serve to distinguish passenger from freight trains. The difference between a chime and plain whistle is in the construction of the bell. The bell of a chime whistle has three different partitions, each of different depth.

LOCOMOTIVE POP SAFETY VALVES.

We present herewith sectional views of the two forms of locomotive pops in general use, one the latest improved Crosby pop, and the other the Meady muffled safety pop.

HOW TO SET POPS.

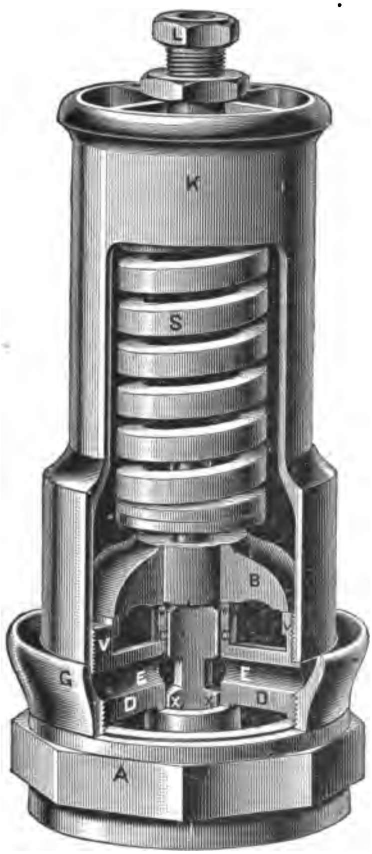
Test each separately by tightening down the spring on the other pop and ascertain which is the most sensitive. Whichever one looses the least steam during a discharge should be used; by this we mean, when the pop springs are properly adjusted it should be the first to relieve the boiler pressure, but it is necessary to set the other one first, which can be done by screwing down the spring on the best pop and then set the other one at a pressure of two or three pounds more than working pressure; then gradually adjust the spring of the best one to working pressure. If either pop loses too much steam during a discharge it may be regulated by adjusting the disc until the discharge is normal. Pops are sometimes set by steam gauge testers, but more frequently under steam pressure. Some safety valves are so constructed that the spring can only be adjusted with a hollow wrench. These wrenches are not furnished to the engine, so it is impossible for a roadman to tamper with the pop, grade or no grade.

ELECTRIC HEADLIGHTS.

While electric headlights are in use upon many roads they have not been universally adopted. They produce a very brilliant and powerful light, yet most roadmen oppose their use, as they are very injurious to the eyesight. The Rogers engine shown on page 275 is equipped with one of these lights.

BELL RINGERS.

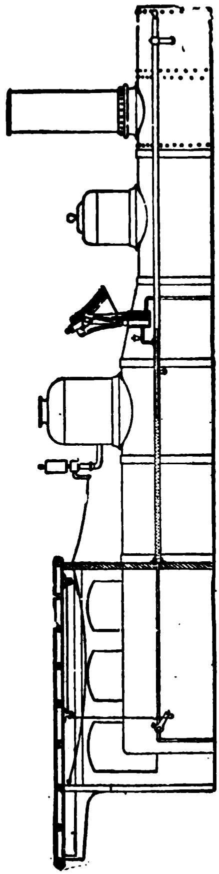
Steam and air bell ringers are in use everywhere, but at present they are used principally upon yard engines and most every road uses a different kind of ringer. We have shown a sectional

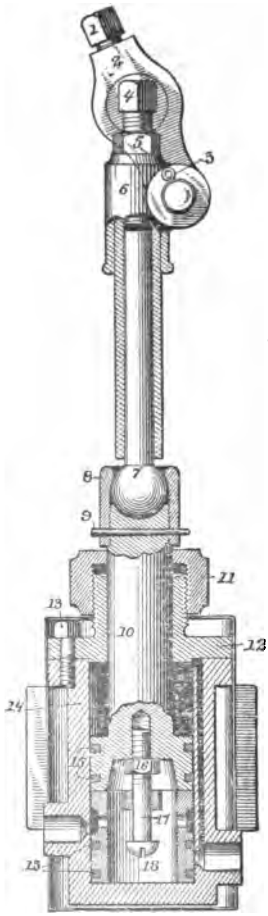


CROSBY'S POP SAFETY VALVE.

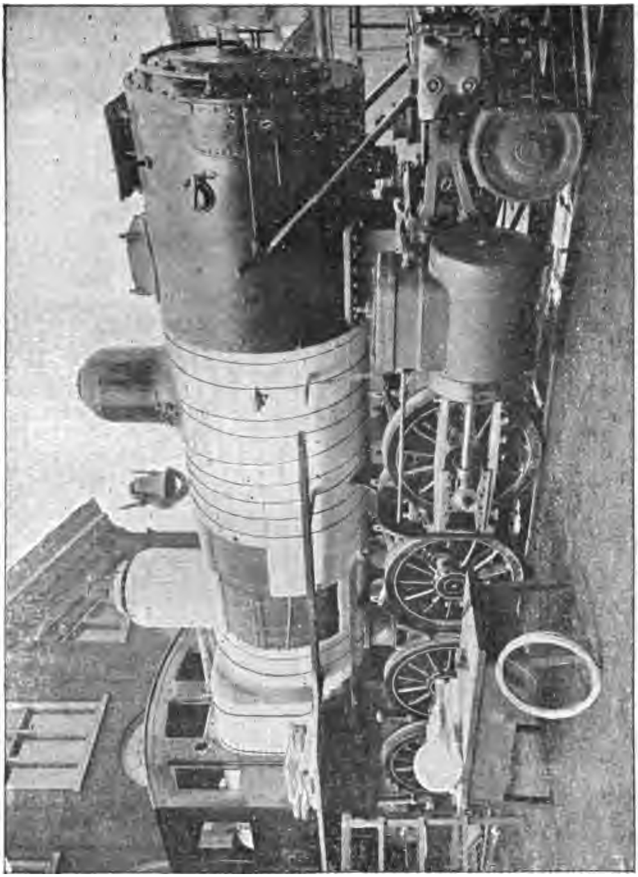
MEADY MUFFLER.

view of one of these devices known as the Gollmar Bell Ringer. We have also shown its method of attachment with the whistle. Every time the whistle is blown the bell also rings, which is very convenient for road service.





GOLLMAR BELL RINGER.



MAGNESIA SECTIONAL LAGGING.

MAGNESIA SECTIONAL LAGGING.

Magnesia is considered the best boiler lagging in use, as it can only be destroyed by abrasion. It is claimed it never chars like wood, or gets hot like asbestos, but when properly

fitted that it will last as long as the boiler. The sectional lagging can easily be removed for inspection purposes. The accompanying cut shows the method of application; the sectional blocks of the lagging are held secure by wire bands.

HOW TO DETERMINE THE HORSE POWER OF AN ENGINE.

To get the area of piston in square inches multiply the diameter of piston in inches by itself, then multiply the product by .7854; this will give the area in square inches. To get the speed of piston in feet per minute, multiply the length of the stroke by 2 (because there are two strokes to each revolution), then multiply the product by number of revolutions per minute the engine is making. This will be the speed of the engine in feet per minute. Take the area of the piston in square inches and multiply it by the mean pressure per square inch on piston, then multiply this product by the speed of piston in feet per minute; now divide the last product by 33,000 and you will have the horse power of your engine.

One horse-power implies sufficient power to lift 33,000 pounds one foot high in one minute, or one pound 33,000 feet high in one minute, or equivalent power.

HOW TO TAP HOLES PERFECTLY SQUARE.

If you are tapping holes on any level surface, use a square to keep your tap true; but when tapping holes on a circle, or you wish your stud to stand at an incline (like studs for steam gauge bracket on back end of boiler head), lay off your holes, then set dividers to any size and scribe a circle; when you have your tap entered well, try dividers from end of tap to your circle, and keep it central.

A POINT WORTH KNOWING.

If you have no glass-cutter or small file, a short piece may be cut off a water glass with two matches, in this way: Wet the sulphur end of one match and mark the inside of the glass all around at whatever point you wish it cut; then ignite the other match, hold the glass over the blaze and keep revolving the glass until well heated, then break the end off with your fingers, and you will find that it makes a nice, smooth cut. Try it.

EXPANSION OF BOILER AND HOW TO MAKE ALLOWANCE FOR IT.

In fitting up expansion plates and buckles, do not clamp the frame, or fit them close, but leave space enough to slip a thin piece of tin between them and the frame. If any bolts go through expansion plates, or buckles and the frame, file and chip the holes oblong ¼" to allow for expansion. Do likewise on back boiler braces—chip oblong holes.

HOW TO LAY OFF FRAME FOR ENGINE TRUCK AND BUILD TRUCK.

Carry a square line across frame in center; find out the distance from center to center of wheels; lay off each center, for each jaw, one-half the distance, carry square line across jaw centers; set all four outside jaws one-half the diameter of box from center line, and tram lengthwise, crosswise, and diagonal. Bolt four end jaws to frame. Put in four boxes and put a strip of tin beside each box, between jaws, then clamp four inside jaws to box, and front jaw, and lay off, drill and rosebit holes, and bolt down solid. Keep all jaws true with straightedge both ways.

BUMPER CASTINGS.

Set faces of bumper beam castings true with front faces, and same distance from front face of cylinders.

MAKING FITS TO THE BOILER.

First level, or square up as it should be when finished. If a fit is to be made on top or bottom of boiler, hold the points of your hermaphrodites perpendicular while you mark it all around. If it fits on the side of the boiler, hold the points of your hermaphrodites horizontal while you mark it all around. So many mistakes are made by holding the points of the hermaphrodites on a line with the center of the boiler all around, which makes a larger circle, and therefore will not fit. Many good men make this error every day.

HOW TO LEVEL UP STACK BASE BEFORE LAYING OFF.

Put a center in base and drop a plumb bob to center of the exhaust nozzle, or center of exhaust port openings, and then level both ways with a spirit level, and lay it off.

ADDITIONAL POINTS.

Never tighten the stem of a globe valve very tight, as the stem will expand and cause the valve to stick.

A globe valve should always be connected with the constant pressure against the bottom of the valve; then if the seat is well ground the valve will not leak around the stem, and may be packed at any time.

A safety boiler cock which has a check valve in its end, which will close in case of accident to the cock, is another improvement.

When drilling, rosebitting, reaming or tapping holes in wrought iron or steel, always use oil. For cast-iron or brass do not use oil.

When drilling close work always use a twist drill, draw to center with gouge chisel and face off all holes for head of bolt or nut, and counter-sink all holes for rivets or oil cups.

Never use a washer on an engine when you can avoid it; cut the thread up farther on the bolt or stud, or bore one or two threads out of the nut.

When connecting side rods, eccentric blades and such work, always try them and see how they divide sideways.

Always put a drain cock in the bottom of the boiler check or branch pipe to avoid freezing.

Manure put into a boiler will stop small leaks.

Never use rubber gaskets for steam-tight joints where you can use copper.

Spring hanger gibs are being replaced with round steel pins.

Allow from ¾″ to 1¼″ draw on all spring hangers; be governed by the dimensions, number of leaves, etc., and weight of the engine.

Many roads use a soft plug (filled with lead or some alloy which fuses at low temperature), in the crown sheet, to avoid burning the engine. They have proven very successful.

The old style expansion plates and buckles are being replaced with two heavy cast-iron plates. One is fastened to the boiler and the other to the frame; a long key holds them intact.

The plunger oil cups are considered the standard for main and parallel rods. Most all oil cups now made use an iron stem, which is much stronger than brass.

When grinding steam-tight joints use coarse emery on iron and flour emery on brass. You should always make at least ⅛″ of good bearing to secure a good joint.

Cast-iron running board brackets are now used; also sheet-iron running boards.

The channels of solid parallel rods are sometimes filled with rubber to deaden the noise.

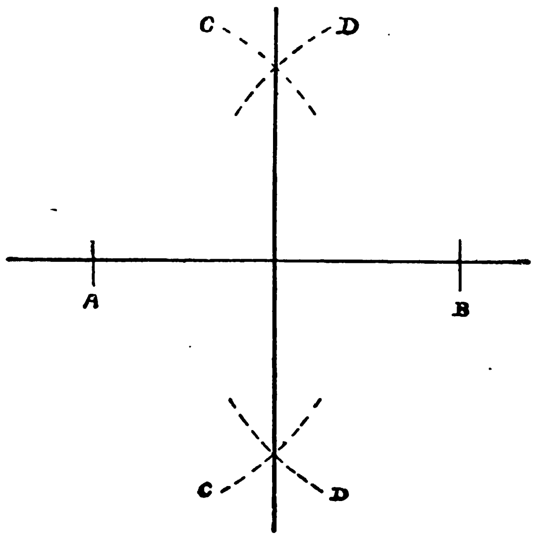
A little giant boiler-washer, which will wash out a boiler with hot or cold water, is used extensively.

Hollow crank pins are used on many roads. They will withstand a greater strain than solid pins.

An automatic closing valve for steam fountains is another new device. It acts as a safety valve in case of an accident, and can be closed at any time to repack any of the cocks.

HOW TO MAKE A PERFECT RIGHT ANGLE.

First make a straight line, and make two centers upon it, as A.B., any distance apart. Now set dividers any length, and from center A mark the two lines C and from center B mark the two lines D. Now from the two points where lines C and D cross, make your square line.

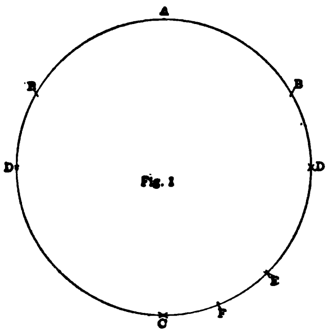


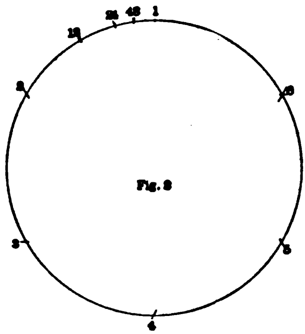
DIVIDING A CIRCLE.

(FIG. 1): 2-4-8-16-32-64-128.

(FIG. 2): 3-6-9-12-15-18-21-24-48.

In FIG. 1 set your dividers to A, any size, and scribe lines B; then from the two points marked B, find C. This divides your circle into two parts. Find center between A and C and make center D. This divides circle into four parts. Now find the distance between center C and D and mark E, and you have



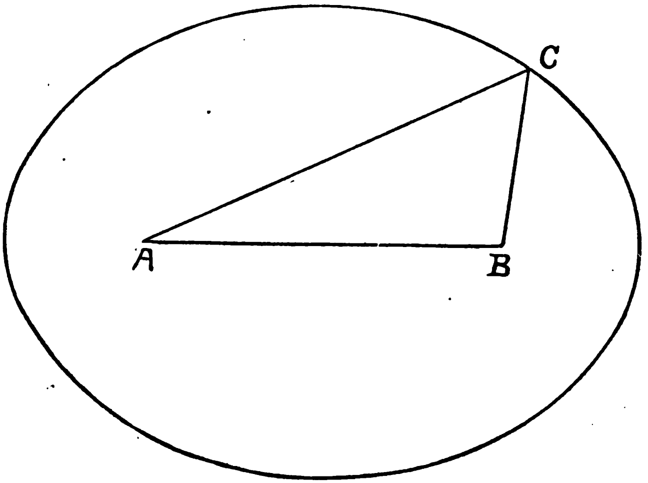


circle divided into eight parts. Now find center between C and E and mark center F. Now it is divided into sixteen parts, and so on.

FIG. 2: We know that dividers set to one-half the diameter of the circle will divide it into six equal parts. Mark each of the points 1-2-3-4-5-6. Now set dividers from 1 to 3, and you have your circle divided into three parts. Now divide the space from 1 to 3 into three equal parts, and circle is divided into nine parts. Now find center between 1 and 2, and you have twelve parts. Now divide space between 1 and 3 into five parts and you have fifteen equal parts. Divide space between 1 and 3 intc six parts and you have eighteen equal parts. Divide space between 1 and 3 into seven equal parts, and you have twenty-one equal parts. Now divide 1 and 12 into two equal parts and you have twenty-four parts. Now divide 1 and 24 into two parts, and you have forty-eight parts, and so on.

HOW TO MAKE AN OVAL.

The most simple and quickest way to make a perfect oval is the string method. Tie a string so as to make it endless, use two pins or tacks for centers, and place the loop over both

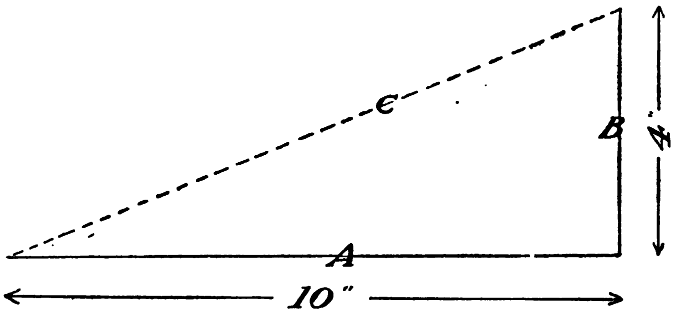


centers and use the pencil inside the loop and mark it off. In the accompanying sketch, the angle inside represents the loop, and A, B represents the two centers, and C the pencil. By moving the two centers you can make the oval any length or width desired.

HEIGHT AND DEPTH MEASUREMENT.

If you wish to lay off holes on any surface where the center is above the face, like a back cylinder head or glands, or to tram pins of different lengths, the following rule is very simple and accurate:

Say you wish to lay off holes on a 20″ circle on a back



cylinder head, and the face for the guide blocks is 4″ above the face where you wish to lay off the holes. Take a two-foot square and scribe line A and B on a face plate; make line A 10″ long and line B 4″ long, and then set your dividers to line C and you have the exact length to lay off the circle.

HOW TO FIND THE CENTER OF ANY PART OF A CIRCLE.

This rule will be found very useful in ascertaining the correct diameter of a cylinder patch, or anything of that kind. To find the center of a portion of a circle, two perpendicular lines must be erected from the circle, and the point where those two lines cross indicates the correct center of your circle. First, divide the portion of the circle which you have into two parts as A, B, C. It is not necessary that the two parts should be of equal length. Now set dividers to any length, and from the two points marked A and C make the four short lines marked D, and from the two points where lines D cross, erect the line marked F. Now from the two points marked C and B make the four short lines marked E, and from the two points where they cross erect line G. Now the point where lines F and G cross, marked H, indicates correct center of circle.

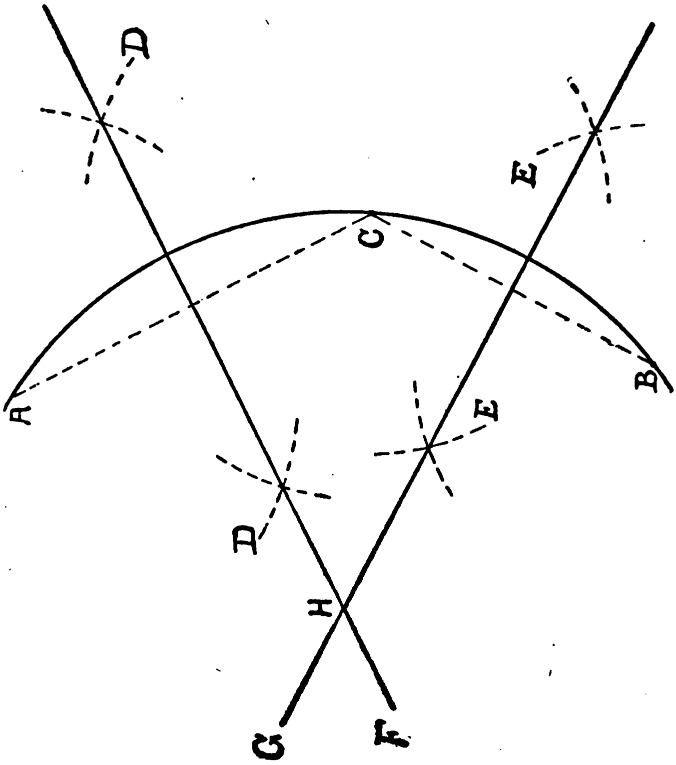

D
E
C
A
B
E
D
H
G
F

TABLE OF U. S. STANDARD TAPS.

Diameter.	Number of Threads. U. S. Standard.	Number of Threads. Other Threads used.	Diameter.	Number of Threads. U. S. Standard.	Number of Threads. Other Threads used.
1/8	48	....	1 1/4	7	....
5/32	40	32	1 5/16	7	....
3/16	24	32	1 3/8	6	....
1/4	20	18-22-24	1 7/16	6	....
5/16	18	16-20	1 1/2	6	....
3/8	16	14-18	1 5/8	5 1/2	5
7/16	14	12-16	1 3/4	5	....
1/2	13	12-14	1 7/8	5	4 1/2
9/16	12	14	2	4 1/2	....
5/8	11	10-12	2 1/8	4 1/2	....
11/16	11	12	2 1/4	4 1/2	....
3/4	10	11-12	2 3/8	4	....
13/16	10	9	2 1/2	4	....
7/8	9	10	2 3/4	4	....
15/16	9	8	3	3 1/2	....
1	8	....	3 1/4	3 1/2	....
1 1/16	8	....	3 1/2	3 1/4	....
1 1/8	8	7	3 3/4	3	....
1 3/16	8	7	4	3	....

TAP DRILL SIZES FOR U. S. STANDARD THREAD.

Size.	Diameter of Drill.	Size.	Diameter of Drill.	Size.	Diameter of Drill.
1/4 in.	0.189	5/8 in.	0.512	1 3/8 in.	1.167
5/16 in.	0.244	3/4 in.	0.625	1 1/2 in.	1.292
3/8 in.	0.298	7/8 in.	0.737	1 5/8 in.	1.398
7/16 in.	0.349	1 in.	0.844	1 3/4 in.	1.500
1/2 in.	0.405	1 1/8 in.	0.947	1 7/8 in.	1.625
9/16 in.	0.459	1 1/4 in.	1.072	2 in.	1.722

The above table gives the diameter of drills in thousandths of an inch for holes to be tapped U. S. Standard, and is an allowance above actual bottom diameter size of thread of from four thousandths of an inch for a 1/4-inch tap to ten thousandths for a 2-inch tap.

STANDARD DIMENSIONS OF WROUGHT IRON PIPE.

BRIGGS' STANDARD.

DIAMETER OF TUBE.			THICKNESS OF METAL.	SCREWED ENDS.		Size to Drill Holes for Tapping.
Nominal Inside.	Actual Inside.	Actual Outside.		Number of Threads per Inch.	Length of Perfect Thread at Bottom.	
1/8 in.	0.270 in.	0.405 in.	0.068 in.	27	0.19 in.	5/16 in.
1/4 in.	0.364 in.	0.540 in.	0.088 in	18	0 29 in.	7/16 in.
3/8 in.	0.494 in.	0.675 in.	0.091 in.	18	0.30 in.	9/16 in.
1/2 in.	0.623 in.	0.840 in.	0 109 in.	14	0.39 in.	5/8 in.
3/4 in.	0.824 in.	1.050 in.	0.113 in.	14	0.40 in.	7/8 in.
1 in.	1.048 in.	1.315 in.	0.134 in.	11 1/2	0.51 in.	1 1/8 in.
1 1/4 in.	1.380 in.	1.660 in.	0.140 in.	11 1/2	0.54 in.	1 7/16 in.
1 1/2 in.	1.610 in.	1.900 in.	0.145 in.	11 1/2	0.55 in.	1 11/16 in.
2 in.	2.067 in.	2.375 in.	0 154 in.	11 1/2	0.58 in.	2 3/16 in.
2 1/2 in.	2.468 in.	2.875 in.	0 204 in.	8	0.89 in.	2 5/8 in.
3 in.	3.067 in.	3.500 in	0.217 in.	8	0.95 in.	3 1/4 in.
3 1/2 in.	3.548 in.	4.000 in.	0.226 in.	8	1.00 in.	3 3/4 in.
4 in.	4.026 in.	4 500 in.	0.237 in.	8	1.05 in.	4 1/4 in.
4 1/2 in.	4.508 in.	5.000 in.	0.246 in.	8	1.10 in.	....
5 in.	5.045 in.	5.563 in.	0.259 in.	8	1.16 in.	....
6 in.	6 065 in.	6.625 in.	0.280 in.	8	1.26 in.	....
7 in.	7 023 in.	7.625 in.	0.301 in.	8	1.36 in.	....
8 in.	7.982 in.	8.625 in.	0.322 in.	8	1.46 in.	....
9 in.	9 000 in.	9.688 in.	0.344 in.	8	1.57 in.	....
10 in.	10.019 in.	10.750 in.	0.366 in.	8	1 68 in.	....

Taper of conical tube-ends, 1 in 32 to axis of tube (3/4-inch per foot, or 1/16 inch per inch).

SHRINKAGE.

Allow on all tires 1-100 of an inch for each 12″ in diameter.

1 1/4″x1 1/2″ finished cylinder band, allow 1/8″.

1 1/4″x1 1/2″ rough cylinder band bored out, allow 3-16″.

1 1/2″x1 1/2″ rough band for hub of wheel and pin hub, allow 1/4″ to 5-16″.

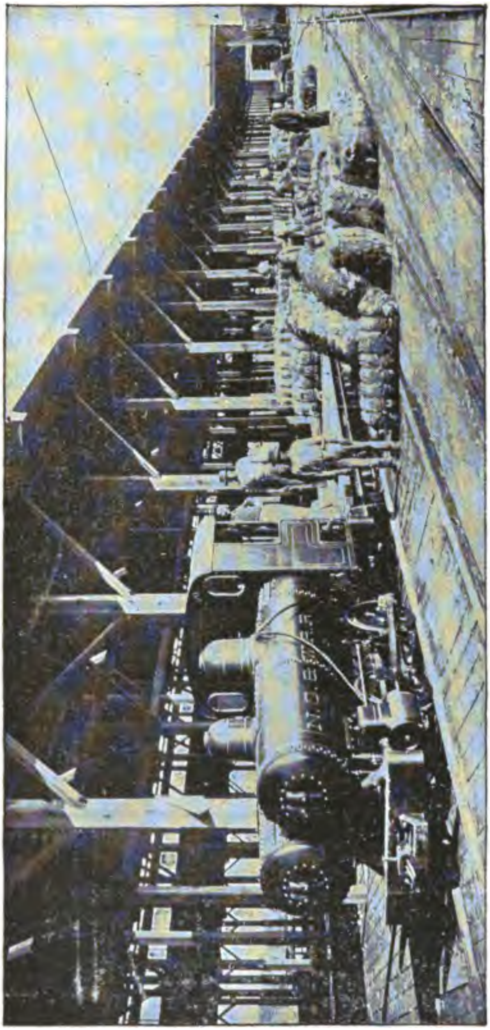
1/2″x3/4″ finished air pump band, allow 1 16″.

1/4x1/2x3″ finished band, allow 1-32″.

and other bands in proportion.

COMPRESSED AIR.

We are indebted to Dr. Denys Papin, who lived nearly two centuries ago in the town of Blois, France, for the first suggestion of conveying compressed air through pipes as a means of transmitting power. His fertile brain conceived the idea of conveying parcels through a tube by means of compressed air; but, like many other great inventions, its real value was not at that time appreciated. We do not again hear of any atmospheric systems of propulsion until 1810, when George Medhurst took out a patent in England, "For a means of conveying goods, letters, parcels and passengers by means of a tube and a blast of compressed air." From that time on compressed air began to be recognized as a simple and valuable power, and it grew constantly in popularity. When Air Brakes for railroad trains were invented it gave compressed air such an impetus that it has since been used for almost every conceivable purpose; in the last decade, with the advent of improved air compressors, its growth has been phenomenal, until to-day compressed air is used for a greater variety of purposes than any other known power. It lacks the objectionable features of the other forces, such as fire, smoke, heat and electricity. It is cleaner and more desirable for use, especially where combustible material is stored or handled. It has been wisely remarked, "That if a fractional part of the brains and money that have developed electricity had been spent on air, our street cars would be running by air to-day." Compressed air is yet in its infancy. Perhaps the most beneficial use made of air so far is upon the air brakes of railways, although it is used as a means of propulsion on a few railway locomotives, numerous mining locomotives, stationary engines, elevators, street cars, mining coal, drilling rock, pumping water, and for transmitting cash, letters and packages, and in a few of the larger cities it is piped throughout the city and sold by the cubic foot; the city of Paris, France, using 25,000 horse-power daily. We will not attempt to enumerate the many uses made of compressed air, but will confine ourselves to its use as applied to railways, which will be more interesting to our readers.



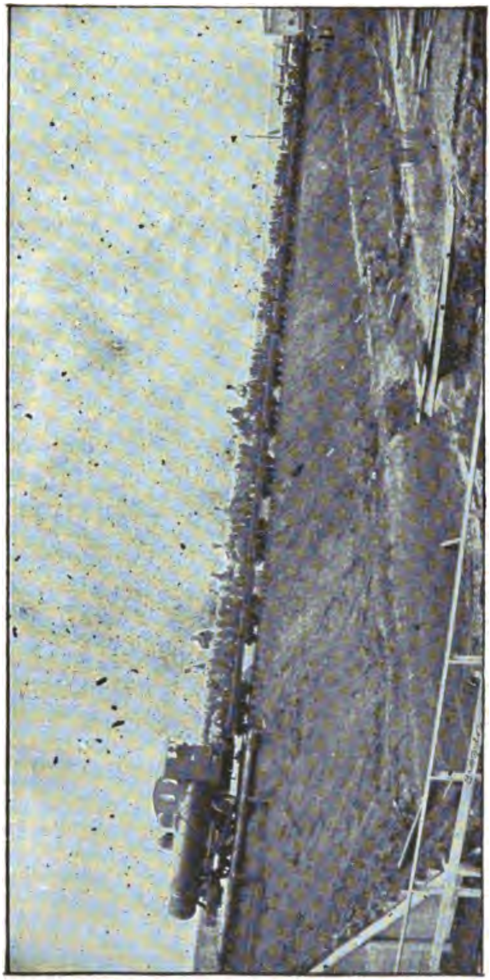
COMPRESSED AIR LOCOMOTIVE.

PNEUMATIC LOCOMOTIVES.

We herewith present views of a pair of compressed air locomotives used at the Chalmette Cotton Warehouse and Yards of the New Orleans and Western Railway. One illustration shows a locomotive with a train at the sheds loading with cotton bales, the other shows a locomotive hauling a train of nine cars loaded with 80 double bales of cotton, total weight of cars and loads 92 tons, up a grade of 3 per cent. The cotton is brought to the yards in ordinary loose bales loaded in standard gauge cars, the bales are then handled by the air locomotives, and after being compressed so that two bales take up about the same space as one ordinary bale, they are then hauled to the wharf and loaded for export. The system of tracks is very extensive, the average round trip being about one mile. This plant occupies about 250 acres and contains 80 cotton warehouses, hydraulic presses, air compressors, etc. The service is necessarily irregular; at times the locomotives have little work to do and at other times, when vessels loading 11,000 bales come in, the locomotives are kept busy. These locomotives were especially built for this railway company by H. K. Porter & Co., Pittsburg, Pa. Their general description is as follows: Weight of engine, 25,000 lbs; air capacity, 160 cubic feet; maximum charging pressure, 600 lbs.; ordinary pressure, 400 lbs.; gauge of track, 36″; maximum grade, 3 per cent; sharpest curves, 75 feet radius. In these locomotives the air is passed through a hot water tank before passing into the cylinders, which increases the efficiency of the air. Air locomotives are also used by many large manufacturing plants on account of the absence of smoke, which renders it feasible to run them inside of buildings where operations are being carried on to which fire or smoke would be fatal. Many of them are also used in coal mines in preference to the dangerous electric cars, and where steam could not be used on account of the smoke. They also furnish an additional supply of fresh air in a mine.

OTHER USES OF COMPRESSED AIR UPON RAILWAYS.

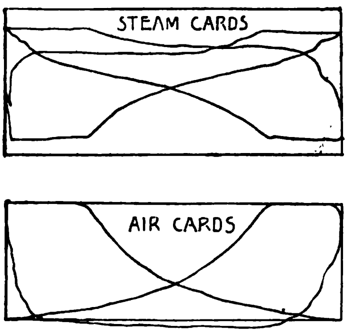
In addition to its use in railroad shops, which we have treated at length, its principal use upon railways is the air brakes, but it is also used for signals and switches, for pumping water, for bridge building, bell ringers, and pneumatic sanders, signal whistle, and for heating trains with the exhaust from the air pump, and for many other purposes which are constantly increasing.



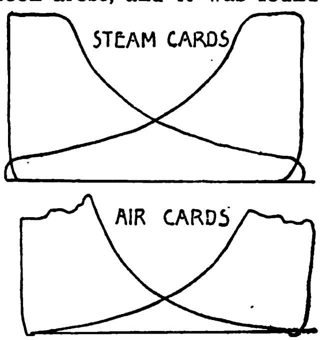
COMPRESSED AIR LOCOMOTIVE.

AIR COMPRESSORS.

The perfection of economical air compressors is, perhaps, the direct cause of the abnormal growth in the use of compressed air during the last few years. The use of compressed air has developed and become established more rapidly and more fully in the railroad shops of the country than anywhere else, simply because it has been easy to produce a supply of the compressed air and to augment the means of compressing it as the demand of its service increased; this, of course, was the direct outgrowth of the air brake. Most every small shop used one air pump to supply air for the shop, while the larger shops were obliged to use from ten to fifteen pumps to supply the demand and the growing needs and uses made of the air. The question of economy soon arose, and it was found



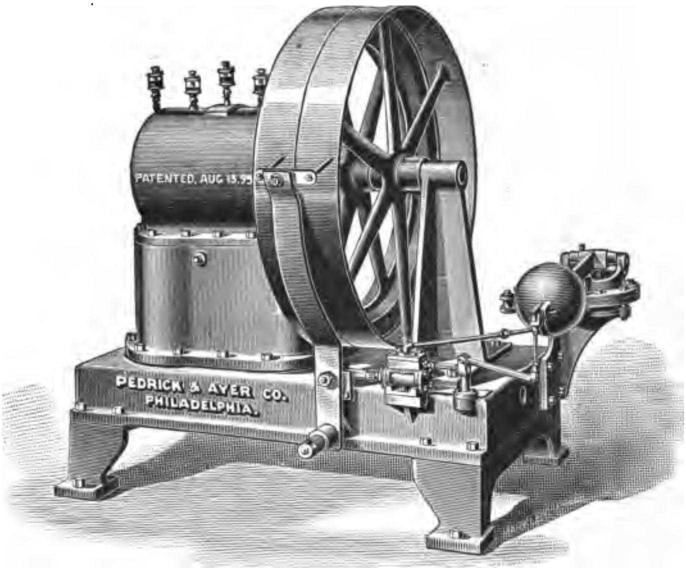
AIR BRAKE PUMP.



COMPRESSOR.

that air could be supplied by a good air compressor much cheaper than by using air pumps. Many experiments were made, and at last an official test was made under the auspices of the Railway Engineering and Mechanics of Chicago, in October, 1894. The result of the test was remarkable and is embodied in the following words: "We find that air brake pumps use 5¼ times as much steam as the compressor." The reason for this result will be apparent to anyone who will examine the diagrams taken at that time, which speak for themselves. Regarding the brake-pump cards, the steam distribution is so abnormal as to need a word of explanation: First, we should say that the steam cards from the brake pump are not wrong-side up, as might be imagined; on the contrary, they represent the real cards, the lower line of which shows

the enormous back pressure in the steam cylinder, this back pressure being introduced for the purpose of offering a resistance to the motion of the piston in the early part of the stroke, to make up for the fact that during this portion of the stroke the resistance offered by the air is very small. It will be seen that as the air pressure increases the back pressure diminishes until at the end of the stroke, when the expulsion of the air takes place, the back pressure becomes very small.



Examination of the air cards will show that another serious loss is introduced in consequence of the absence of a crank, which causes the piston to stop before the end of the cylinder is reached, which action prevents the free expulsion of the air from the cylinder. Compressors are made in all sizes and for all purposes, and there are about as many designs as there are of the stationary engines. We illustrate a very simple belt compressor, especially adapted for use in railroad shops. It regulates itself automatically, maintaining the pressure at any desired point. It is compounded and water jacketed. It runs only so long as air is being used and delivers 44 cubic feet of free air per minute.

THE AIR HOIST.

Air hoists are an invaluable addition and improvement to railroad shops, where so much heavy material is constantly handled, and they have superseded the old rope and chain pulleys wherever air is in use. These hoists are made both vertical and horizontal, so they can be used under low ceilings or located to clear shaftings, cross beams, or other supports. They are attached to cranes of all kinds, hung from rods, rafters, beams, or other supports, and are moved to all parts of the shop by means of transverse pulleys and guide bars. They are in use everywhere in large shops and used for all purposes. The vertical hoist which we have illustrated is the kind most generally used in machine shops; they have an automatic stop and retaining valve, only admitting enough air to raise and keep the load at the desired height, giving the operator the free use of both hands to adjust his work in the lathe or other machine. The horizontal hoists are usually attached to cranes. They operate a chain pulley attachment and can be locked and sustain their load indefinitely, air or no air. The following are a few of the uses made of the air hoist in the machine shop: Lifting heavy material for planers, boring mills, lathes, slotters, drill presses, and various other machines; handling air pumps, stacks, front ends, steam chest covers, and other such work in the erecting department, and transferring material to different parts of the shop. In boiler shops and blacksmith shops large sheets and heavy forgings are handled. In the roundhouse, stacks, air pumps and other work is handled, while outside, tires, castings, and such things are moved around and cars loaded and unloaded. We give a table of the lifting

capacities of direct acting hoists with a maximum pressure of 80 lbs. and the cubic feet of air used for each full lift:

Diameter.	Capacity.	Lift.	Cubic feet.
3 inch	400 lbs.	4 feet	1.04
4 inch	825 lbs.	5 feet	2.32
5 inch	1,450 lbs.	5 feet	3.63
6 inch	2,100 lbs.	5 feet	5.33
7 inch	2,600 lbs.	5 feet	7.12
8 inch	3,750 lbs.	5 feet	9.55
9 inch	4,300 lbs.	5 feet	11.78
10 inch	6,000 lbs.	5 feet	14.54
12 inch	8,500 lbs.	5 feet	20.94
14 inch	12,000 lbs.	5 feet	28.05
16 inch	15,800 lbs.	5 feet	37.23

In many shops they make their own air hoists out of wrought iron pipe. A simple method for cleaning out the inside of the pipe for this purpose is to force a steel die through the pipe. This method is successfully used in one of our large railroad shops.

AIR MOTORS.

The air motor is another valuable tool in railway shops. They are made in all sizes and adapted to almost every use, in some cases replacing steam power, but more often, perhaps, performing work which was formerly done by manual labor, doing the same work much more rapidly. The following is a partial list of the uses made of the air motor in railroad shops: Propelling separate machines when working overtime, or at times when the stationary engine is not in use; driving grindstones, emery wheels, fans, or machines in small shops or round-houses; drilling, tapping, reaming, and screwing, all kinds of work. In the erecting department of machine shops, driving cylinder boring bars, valve facers and flexible shafts and turning the rollers when setting valves. In the boiler shop it is used for drilling, tapping, and screwing in stay bolts and other work; running portable drills, rolling flues, and supplying blast for forges, In the blacksmith shop and copper shops they are used for blast purposes. In some places they propel the transfer table. Sandpapering cars is another use to which it is put.

JACKS AND PRESSES.

Many shops use air jacks in their drop pits, where it is laborious and sometimes dangerous to use hydraulic jacks. Air

presses are used for various purposes. They are used for bending air brake and other pipes, wooden dies being used for forming the pipe, also for punching and shearing and driving out old bolts. For applying couplings on air brake hose and for pressing and forming tinware. Long presses similar to air hoists are also used in boiler shops for holding sheets while chipping, and other kinds are used for flanging and forming. In the blacksmith shop and yard they are used for straightening old iron rods.

PNEUMATIC HAMMERS.

Pneumatic hammers are used for beading flues, riveting tanks, calking, and chipping castings, and all kinds of extensive hammering.

OTHER USES MADE OF AIR IN RAILROAD SHOPS.

Running engines out of the shop, kindling fires, cleaning flues, cleaning out lubricators, oil cups, eccentric strap oil cellars, blowing out pipes, sifting sand, fire alarm whistles, breaking old castings, sanding car roofs, whitewashing, cleaning cars, cushions, etc., and pumping water. The above list is incomplete, but is sufficient to give the reader a fair knowledge of the uses and advantages of a supply of compressed air in any shop.

LOCATING BLOWS AND POUNDS.*

HOW TO LOCATE A BLOW IN AN ENGINE.

A locomotive produces so many deceptive blows that it is sometimes very difficult to determine the location of a blow. We will first call attention to a few of the parts where blows occur most frequently and describe the various sounds, and the action of blows under different circumstances, which may assist in determining the location of the blow before a test is made, we will then explain the correct way to test the engine and determine the location of a blow. A blow may be in the cylinder packing rings, the valve seat, the gibs, rings or rider of a balanced valve, or it may be in the steam pipes or nigger-head, or it may be a crack or a hole in the steam ports. If it is an intermittent or recurring blow, a round roaring, rumbling sound, like whor-r-r-r, you may depend upon it being in the cylinders, and you can usually locate in which cylinder it is by watching the crank pins on a slow pull, as it will usually be worse when the piston is in the center of the cylinder. If it is a continuous sharp, shrill sound like whis-s-s-s, it is usually in the valve seat, but a valve sometimes blows intermittently when the valve cocks at one end. If it is a strong continuous blow and you have balanced valves it is possible one of your valve strips, valve springs, rings or rider is broken. But if your engine has a plain slide valve reverse the engine two or three times real quick, as it may be only a cocked valve. Remember balanced valves do not cock. It may prove to be a sand hole in the valve or between the ports. A steam chest blow is easily distinguished from a steam pipe blow because it will blow straight up the stack and make a clear, singing sound, while a steam pipe blow expends its force in the front end and makes no noise when going out the stack. A steam pipe blow if very bad will affect the draft of the fire and when the fire door is open it sounds like a leaky stay bolt. A good indication of a steam pipe leak is the appearance of water in

*The following chapter was especially prepared for this book by Mr. J. P. Hine, member Division No. 37, B. of L. E., whose many years of service have well fitted him for the work.

the front end. If you have lost one exhaust it may be a slipped eccentric; as a slipped eccentric will usually cause the valves to sound out of square. A valve yoke cracked or broken on one side only will cause one exhaust to sound out of square while the other three are perfect. When the valve stem breaks off it will usually cause a tremendous blow which will continue so long as the throttle remains open. But if you have a tremendous blow at one point only, and have lost one exhaust, and the three remaining exhausts are perfect, it may be a broken bridge or crack, or a sand hole in the bridge. Notice the cylinder cocks before you stop and see if steam appears at only one cylinder cock when the piston is at one end of the cylinder, and at both cocks when at the other end, if so it is a very good indication of a broken bridge, but examine your eccentrics as soon as you stop. When an engine has a bad blow when in full gear which disappears when hooked up a few notches, it indicates that the valve travels too far and opens the exhaust port to direct steam chest pressure. This is sometimes caused by the top arm of the tumbling shaft working loose, perhaps the key is lost. When the exhaust nozzle is gummed up it produces a sort of asthmatic wheeze, or whistle, which is sometimes mistaken for a blow. When two exhausts are heavy and two very light you may have blown out a nozzle tip, providing you have double nozzles. When the dry pipe leaks the engine will work water through the cylinders and when standing in the round house it may be discovered by a constant leak at the cylinder cocks.

A leak at the bottom of the exhaust pipe will not cause a blow, but will affect the exhaust.

METHOD OF TESTING AN ENGINE FOR A BLOW.

From the descriptions we have given of different blows, you can usually determine about where the blow may be found and proceed to test that particular part without giving the engine such a severe test as we have outlined, as this chapter necessarily covers all kinds of blows. We will first test the steam chest, and afterward the cylinders. It is an easy matter to determine which cylinder a blow is in, but it is sometimes very difficult to locate which steam chest, so follow these instructions closely.

Place each rocker arm in a vertical position alternately, block the wheels, open the cylinder cocks and give the engine a little steam. If no steam appears at either cylinder cock you may depend the valve seats are tight. If your engine has balanced valves test the valve strips, rings or riders. A blow of this kind is sometimes very difficult to locate, but it can be

done, viz.: [The McDonald valve, which we have illustrated and described on page 53, has a cock on top of the steam chest for this very purpose.] If your engine has drain cocks screwed into the exhaust port, go under the cylinders and open the cocks and have the fireman give a little steam; if steam appears at either cock that is the side your blow is on. Another way is to open the front end if you have a double nozzle, and you can see which side blows; if a single nozzle, climb up on the boiler and by feeling the draft on each side of the stack with a broom, or lighted torch if at night, you can usually notice a difference in the draft. On whichever side the draft is the strongest the blow will be in the opposite chest. Or, you may put a little fresh coal in the fire box and watch its action on the smoke. This kind of a blow can sometimes be located by the increased friction, which will cause the valve stem to jerk when in motion, or it may be discovered by placing the crank pins on center alternately and handling the reverse lever under steam pressure, the blow will be on the side that handles the hardest while the pin is on the quarter (not the center). Hoping these suggestions will assist you, we will return to the valve seat.

Now if steam does appear at both cylinder cocks on one side while the steam ports are covered, it is evident that the valve seat on that side leaks, providing the opposite side is tight; the leak may be in the valve seat or beneath the false seat, or if the valve has inside clearance it may be a flaw in the valve. If steam appears at only one cylinder cock on only one side of the engine, while the ports are covered, it may be a sand hole between the supply port and the steam port, but it is more probable a false seat loose on one side. If steam appears at the forward cylinder cock, the forward end of the false seat is loose, and if at the back cylinder cock, the back end. Now if steam appears at both cylinder cocks on both sides it is evident that the valves on both sides blow.

We will now proceed to test the cylinder packing, placing each main pin on either quarter alternately, and with the reverse lever in the forward notch give the engine a little steam. If steam escapes at only one cylinder cock the cylinder packing on that side is all right, but before leaving it place the reverse lever in the back notch and try it there. Now if steam appears at both cylinder cocks when one port is open, and at only one cock when the other port is open it indicates a broken bridge, (although a broken valve strip or ring might cause this, or a sand hole in the bridge below the valve seat); which particular bridge is broken may be determined by noticing which port is open when it shows steam at both cylinder cocks; if the forward port is open then it is the forward bridge, and vice

versa. A broken bridge can usually be determined from a crack, or sand hole by a tremendous blow. If steam appears in great volume at both cylinder cocks when the lever is in both motions, it is then impossible to say whether it is a broken valve seat or broken cylinder packing rings, so have the cylinder head removed first; if it is all right then you know it is the valve seat. A broken cylinder packing ring can usually be distinguished from one that simply leaks by the volume of the blow. A packing ring that leaks will also show steam at both cylinder cocks when in both motions, but it will not be such a heavy blow as a broken ring will produce. Most every engineer has had some experience with packing rings that simply blow and can distinguish it from anything extraordinary, such as a broken packing ring or bridge. When you raise the steam chest cover first examine the rings, or valve strips and springs. See that the valve strips do not fit too tight on the ends, for the long strips expand 1-32″ more than the valve and often cramp the short strips. Next examine the valve seat and face, then the bottom joint of a false seat, and the pressure plate, and face off all joints that need trueing up. Now examine the valve carefully for sand holes. If you cannot locate the blow elsewhere then fill the supply ports with water (one at a time); open the cylinder cocks and see if it leaks water; if it does there is certainly a sand hole or crack, if not then fill the cylinder and steam ports and see if it leaks into the exhaust cavity. Open drain cock at bottom of the exhaust cavity.

CAUSE OF VALVES SOUNDING "OUT OF SQUARE."

Sometimes an engine's valves will sound "out of square" when the valve gear is perfectly adjusted. The following is a list of causes which may produce such an effect:

Driving wheels improperly quartered.
A main driving axle bent.
A patch inside the steam ports, or ports of different size.
Cylinders of different size (not compound engines).
Eccentrics of different throw.
Links of different radius.
A hole in the petticoat pipe or stack.
A leak at the exhaust pipe joint.
A valve-yoke cracked on one side.
Cylinders working loose on the frames.

POUNDS.

What is known as a pound in a locomotive is often the cause of much annoyance to the engineer, and, like a blow, it is some-

times very difficult to locate, and in addition to the annoying sound, if a serious pound is neglected it may be the cause of breaking a crank pin, cylinder head or some other part of the engine. So as soon as a pound is located it should be reported without delay, and thereby relieve the engineer of further responsibility. An experienced engineer who is familiar with the various sounds produced by a locomotive can very often locate a pound by its particular sound. The best way to locate a pound is to place the engine on the top quarter, block the driving wheels and have the fireman give the engine a little steam and reverse her, and watch all points on that side where she is liable to pound. Knocking or pounding may be caused by an insufficient oiling of the cylinders, main shaft, main crank pin, or cross head pin or lost motion in any of the reciprocating parts, such as the main rod brasses, loose cross head pin or loose crank pin, or a bad fit between piston rod and cross head or piston. If a piston strikes the cylinder head it will cause a knock, too loose wedges, or loose knuckle pin or bushing, or loose middle connecting brasses. Wedge down, or when wedges are stuck they will also cause a thumping sound. A broken engine frame or loose cylinders or loose deck will also cause a bad pound. Very loose pedestal braces on light frames will sometimes cause a pound. Imperfect fitting up of the shoes and wedges while undergoing repairs is also a cause of many pounds; when finished the shoes and wedges should be perfectly parallel and not bind the box on either top or bottom, leaving the other end loose, which is sure to cause a pound. Another cause of pounding in the driving boxes is loose oil cellars; cellars should be a good, close fit into the driving box, as the weight of the engine and the constant wear of the brass tends to close the box at the bottom, which, if permitted, would eventually cause a pound. The driving box wears the surface of the shoe and wedge against which it rubs, while the surface extending above the box, not being subject to wear, naturally causes a shoulder to be worn on both shoe and wedge, which is a frequent cause of the box sticking and causing a pound; it is for this reason so many roads have the top ends of the shoes and wedges planed off below the wearing surface, and many roads have discontinued the practice of beveling the top edges of the driving boxes to admit oil, as they catch to many cinders, which causes the shoes and wedges and boxes to cut. Oil holes are drilled through from the cellar on top of the box to the wearing surface of the box. Loose driving brasses, either circle or gib brasses, will cause a pound. Square bottom spring bands, or poorly fitted spring saddles or any interference with a free movement of the equalizer will also cause a knocking sound. See that the

springs do not rub the boiler, or the saddle strike the engine frame. Pounds are also caused by wet steam or foaming, causing water in the cylinders. Excessive back pressure will also cause a pound in the cylinders. Imperfectly balanced driving wheels will create a jerking of the engine. Too great or too small a compression will also cause a jerk when passing over the center. For a high speed the compression should be almost, if not quite, equal to the initial boiler pressure; loose deck or loose cylinders will also cause a pound. Lost motion in the valve gear will often cause the reverse lever to rattle; badly distorted valves which cause an unequal distribution of steam often cause a jerking sensation when hooked up near the center notch. Side rods (except the middle connection) will not pound, but will rattle. A loose follower bolt will usually cause a knocking in the cylinder when steam is shut off. Packing springs sometimes cause a sort of clicking sound.

NEW STYLE DRIVING BOX.

A driving box has been invented which is intended to prevent pounds in the box or brass. It resembles the ordinary driving box with three gib brasses, the improvement being that the two side gibs are adjustable, having lugs in their center which protrude through the box and bear against the shoe and wedge, the top gib being pressed into the box in the usual manner. The side brasses extend considerably below the center of the axle, thereby making the bearing about two-thirds the circumference of the shaft.

SETTING UP WEDGES.

First, be sure all the boxes are up tight against the shoe, so that whatever lost motion is in the jaw will be at the back of the box, so the wedges will slip up freely. The best way to do this is to place the pins on the top eighths and pinch the wheels forward, then the rods will tend to force the box up against all the shoes; while if the rods were below the dead center pinching the back wheel forward would tend to draw the forward box back against the wedge. This will be readily understood as the rod would then pull back on the forward pin. When you have all the boxes up tight against the shoes set the wedges up moderately tight with a small monkey wrench, and tighten the jam nuts with a large wrench.

KEYING UP RODS.

This operation will soon be a thing of the past, as most all railroads and locomotive builders have adopted the solid end

side rods. They are much safer and prevent many accidents, but as there yet remain some engines with keyed rods, we will explain how the keys should be tightened, or "set up." First, select a level piece of track without any high or low joints; place the pins on center on one side and beginning with the middle connection drive the keys down with a hand hammer (not the coal pick); then try the rod at both ends and see that it will move laterally and does not clamp the pin. Move onto the other center and try it again; if it is all right tighten the set screws, then place the opposite side on the center and do likewise. When keying up the main rod place the pin on the forward top eighth, which is the largest part of the pin (on a road engine); key moderately tight, then see if you can move it sideways on each bearing; if not slack up the keys a little; then tighten up the set screws. Some engines have so very little clearance that it is safer to key the main rod with the pin on dead center.

HOT BRASSES OR ECCENTRIC STRAPS.

Hot bearings may be caused by a lack of lubrication, over-pressure, grit in the bearings or too high rotation, speed, etc.; much also depends upon the alloy of the metal and the dimensions of the bearing; the larger the diameter and the longer the bearing the less liability of heating so long as everything is kept in line. Tallow, soap or graphite mixed with lard oil are good cooling lubricants for a hot bearing. When a driving brass gets very hot you should relieve the box, as it may be caused by excessive weight; this may be done by running the wheel up on a wedge and then blocking solid between the spring saddle and the frame. Slacking the wedge slightly is another remedy. Many engines are now supplied with a small water pipe which may be turned onto each bearing. When a rod brass starts to throw the babbit don't stop until it is all thrown out; then stop, examine the oil cup and the hole in the strap and see that it is not choked up. Slack the rod key slightly, give it a good oiling and proceed. An engineer usually knows the condition of his eccentric straps, so if you smell a hot bearing and think it is an eccentric strap shut off steam, but don't touch the reverse lever, for if you try to "drop her down in the corner" it will invariably break the eccentric strap. Wait until she stops and then slack the strap bolts a little, and put in a little more liner if convenient. Never cool a cast iron eccentric strap with water. If a truck or tender brass runs hot, replace it or repack the cellar and keep it well oiled. Turn the small hose on it if you have pipes to each box.

BREAKDOWNS.*

The prudent Engineer who inspects his engine regularly and replaces loose bolts, tightens nuts and keys, looks for defects and carefully examines any cracks, flaws or other defects upon his engine is seldom troubled with those annoying and sometimes dangerous breakdowns while on the road. An observant engineer who becomes familiar with the regular and equal exhausts of his engine often detects a lame exhaust in time to stop and prevent a serious accident to his engine, as any defect in the valve motion, such as a loose eccentric, strap bolt, loose blade bolts, a loose valve stem key, a broken valve yoke or slipped eccentric, will cause an imperfect exhaust. But breakdowns sometimes occur after a man has done everything human foresight can aid in doing to prevent an accident. These pages were written to assist those who are so unfortunate as to meet with a mishap on the road, who may through excitement or lack of knowledge omit, or forget, to do something of great importance, which may cause a worse breakage than the first. Numerous cases may be cited where engines have been brought in without performing the amount of work which we say becomes necessary, but those engineers did not take the safe side, and had other breakages occurred they would have been held strictly accountable for their neglect. In case of an accident we presume the engineer will first comply with his book of rules regarding signals, flagman, etc., and will not neglect his boiler while working on a disabled engine. If the engine is in the ditch, or the crown sheet not properly protected, kill the fire immediately. If you cannot secure water gravel will extinguish the fire. These pages only treat on the mechanism of the locomotive. All well equipped engines are supplied with a sufficient number of jacks, hand tools, wrenches, clamps, blocks, etc., to be used in case of an accident, and every thoughtful engineer will see that his engine is supplied with such things before starting out on the road.

*Mr. J. P. Hine also assisted the author in the preparation of this chapter.

HOW TO DISCONNECT AN ENGINE.

In order to save an unnecessary repetition of words, and to assist in condensing this chapter, we will briefly state what is implied when we say disconnect one side. It means to remove the main rods on one side, but not the eccentric straps or side rods, unless clearly stated; and whenever the eccentric straps are removed on one side the top of the link should be tied to the short arm of tumbling shaft to keep from tipping over, which would prevent reversing the engine; and to secure the cross head at the back end of the guides with cross head clamp, or good hardwood blocks, and secure the blocks with rope so they cannot work out, and to set the valve central over the steam ports and secure it there, either with valve stem clamp or with gland. The valve can easily be set to cover the ports by opening the cylinder cocks and giving the engine a little steam, then adjust the valve until steam is entirely shut off from the cylinder cocks. If you have no valve stem clamp the stem may be held secure by cocking the gland and setting the nut tight on one side. Most engines which use metallic packing are furnished with valve stem clamps. Disconnecting both sides means to remove both main rods and both valve rods, and if the engine is to be towed very far see that all oil cups are well filled before starting; in this case it is unnecessary to fasten the cross head or valve stems. Never remove the eccentric blades, leaving the straps on the eccentrics, unless the straps will whirl all the way around and clear the fire box, ash pan and everything else. Take no chances, for you may punch a hole in the fire box. Whenever you have occasion to remove a side rod, always remove the rod directly opposite to it; if it cannot be done, then remove all side rods. When blocking a cross head don't move it clear back to the striking point or you may get the cylinder packing rings down in the counter-bore. Cut your block the length of the stroke, and drive a wedge at the back end, or if you use a cross head clamp place a block or nut between the cross head and the guide block, and open or remove cylinder cock at back end. When blocking the cross head on a pony engine or a ten-wheeled engine when the side rods have been removed it may be necessary to block the cross head at the front end in order to clear the crank pin on the forward pair of drivers. Block it wherever it will clear. If they won't clear at all have the engine towed in. Most all roads are very strict regarding the speed of dead or disconnected engines, as the engine is not then counter-balanced perfectly, and is therefore very injurious to the track. Some of the best roads limit the speed of all heavy engines which are disconnected on

one or both sides, or which have the side rods removed, or dead engines hauled in a train, to twenty miles per hour.

VALVE YOKE.

A valve yoke usually breaks off at the neck of the valve stem. It will be readily discovered by the exhaust by a tremendous blow. If the valve is pushed far enough ahead it will blow; if not, it is often mistaken for a slipped eccentric (examine the eccentrics first). It may be discovered in this way: Place the crank pin on top or bottom quarter and reverse the engine; if the steam still continues to come out of the back cylinder cock you may depend it is usually the yoke. (See how to locate Blows.) A great diversity of opinion exists regarding the best remedy for this kind of a break. The old and safest way is to raise the chest cover and block the ports central, replace the cover, remove the valve rod and main rod and block the cross head at the back end. But this remedy requires much time and labor and as time is a very important consideration on the road, and as there appears to be no mechanical objections to the other methods, providing the cross head is securely fastened, we will state the other remedies. Disconnect the valve rod and push the valve clear ahead, remove the stem if it would blow out, and use a gasket back of the gland, or hold the valve stem intact with valve stem clamp. Block the cross head at the front end, and proceed; the pressure will hold the valve forward and if it should move it can do no harm, providing the cross head is securely blocked. Another way is to remove the release valve, push the valve clear back, fit a block into the release valve long enough to hold the valve back, then block cross head at back end. Still another way is to push the valve stem forward and clamp it by cocking the gland, then block cross head at the front end. If the yoke is only broken at one side of the valve it will only affect one exhaust. When the yoke pushes the valve forward the valves will sound all right, but when it pulls the valve back the engine will be lame. With careful handling you may finish your trip without breaking the other side. Work the engine in full gear with a light throttle.

STEAM CHEST OR COVER.

This is a very troublesome mishap. If you think that the chest is only cracked, remove the casing, and if it is only cracked on one side by wedging between the chest and studs you may be able to close the crack enough to get in. But if it is a bad crack, or a cover, and you have no way of clamping the

broken parts, disconnect one side and then the quickest remedy would be to use a blind gasket at one end of the steam pipe. But that is considered impracticable, owing to the corrosion of the bolts and nuts, the netting and a very hot front end. So remove the chest cover and plug up the supply ports with wood and clamp the plugs with steam chest studs. If steam enters from side of chest use a gasket there. If the chest is completely knocked off, clamp your wooden plugs with old bolts and fish plates, or whatever you can find. Remember many steam chests may be saved, when you have no relief valves, by opening the throttle slightly as soon as you reverse the engine, for a reversed valve gear is virtually an air pump, and if the air cannot enter the boiler it must escape somewhere when compressed.

PISTON OR VALVE STEM GLANDS.

If the gland breaks in two try and wrap it with bell cord or wire. If a lug breaks off make a wooden clamp; you have two nuts on each stud, so remove one of the nuts and tighten the other up against your temporary clamp. If you loosen one stud wrap wire or rope around the steam chest and try to hold it secure, or remove part of the packing and shove gland in further and try to hold it with one stud. If all other remedies fail disconnect one side.

VALVE ROD.

Disconnect on the broken side.

PISTON ROD.

When a piston rod breaks it invariably knocks out the front cylinder head. When the piston is entirely out of the cylinder or if it can be easily removed, then it will not be necessary to remove the main rod. Simply clamp the valve stem central as previously explained. Remove all loose broken pieces and proceed.

CROSS HEAD.

A slight break such as a plate or gib may sometimes be clamped up so you can proceed. But do not interfere with the travel; if it is a bad break disconnect one side.

CRANK PINS.

Main Pin.—Disconnect one side and remove all side rods,

Forward or Back Pair.—Remove the side rod between the broken pin and the main pin, and the side rod directly opposite to it.

MAIN ROD OR STRAP.

Disconnect on the broken side.

SIDE ROD OR STRAP.

Remove the broken rod and the side rod directly opposite it; if that cannot be done remove all parallel rods.

CYLINDER HEADS.

Back.—Disconnect one side of the engine.

Forward.—Disconnect one side of the engine. Another method advocated by many, but practiced by few, by which three-fourths the power of the engine could be retained, is to remove the steam chest cover and plug up the forward steam port with wood and proceed working both sides. This method is impracticable owing to the shape of the steam port cavity on most engines, and the time it would require, as time is usually the most important factor, besides the improbability of the block remaining intact.

SLIPPED ECCENTRICS.

Since the practice of keying eccentrics to the shaft has become so general these mishaps occur less frequently than formerly. Yet every engineer should know how to reset a slipped eccentric. This accident is easily detected, for without any warning the exhaust will become very irregular and you may lose one exhaust entirely. You should immediately stop and go down under the engine, when the cause will be quickly discovered. If you have previously studied the positions of the different eccentrics it will be an easy matter to reset it, but if you are not familiar with the relative positions of the eccentrics you may experience considerable trouble. Every engineer and fireman should familiarize himself with the correct position of each eccentric, and the practice of marking each eccentric and shaft is a very wise precaution, although many roads prohibit the practice of making a chisel mark on the shaft. On all standard engines with indirect motion when the crank pin is on the forward center the go-ahead eccentric will be above the pin, and the back-up below the pin, and when the pin is on

the back center their positions are reversed. The rib of each eccentric is set about the third spoke away from the pin. The spokes in different wheels may vary, but so does the lead and lap. Remember they should never be at right angle with the pin, but each should incline slightly toward the pin. Perhaps the quickest way to set a slipped eccentric approximately correct is that old way of marking the valve stem, which is as follows: Place the crank pin on either dead center on the side that has slipped; the forward center is the most convenient; if the forward eccentric has slipped (the forward motion is always attached to the top of the link), place the reverse lever in extreme back notch of quadrant, and with a knife or some other sharp instrument scratch a line on the valve stem as close as possible to the gland. Now place the reverse lever in extreme forward notch and move the eccentric around until the same line on the valve stem appears, then set the eccentric in that position. If the crank pin is on the forward center the center of the eccentric should be above the pin, and if on back center below the pin. If the back-up eccentric slips go through the same performance in exactly the reversed manner, by placing lever in forward notch and marking the stem, then put in back notch and set the eccentric same as before. If both eccentrics on same side slip set each eccentric as near as possible to the positions we have previously explained. Now place crank pin on forward center, block the wheels, open the cylinder cocks, place reverse lever in back notch and give engine a little steam. Now move back eccentric until steam appears at front cylinder cock, then fasten the eccentric. Now place lever in forward notch and move eccentric until steam appears at same place (forward cylinder cock); then fasten the eccentric and you are done. Many experienced men who are familiar with the position of each eccentric ignore these old rules and set each eccentric by eyesight, when their correct positions are not marked.

ECCENTRIC OR BOLTS.

If the eccentric or bolts which hold the two halves together should break so the eccentric slips on the shaft, or will not turn in the strap, you must disconnect that side and remove both eccentric straps and blades and tie up top of link to tumbling shaft arm so the link won't tip and prevent reversing the engine.

ECCENTRIC STRAP OR BLADE.

If the blade breaks you must use the same remedy as for broken eccentric. If only the jaw of a strap breaks off or holes

break out it is sometimes possible to fasten the blade to the other strap with a long bolt, remove the broken strap, and if the link will clear everything when in full gear then proceed slowly. If you can't do this, then use the same remedy as for broken eccentric. This applies to forward motion only.

SLIPPED ECCENTRIC BLADE.

This defect is easily detected by the irregular exhausts. It can be reset by placing the crank pin on either center; place reverse lever in forward notch, open the cylinder cocks, then adjust the blade until steam appears at the front or back end of the cylinder according to the position of the crank pin. If pin is on forward center steam should appear at front end of cylinder, and vice versa; or it can be set by marking the valve stem same as for slipped eccentric.

TUMBLING SHAFT, ITS ARMS OR STANDS.

If either stand breaks and cannot be clamped together so it can be used (a wooden block is sometimes used in place of a stand); remove both link hangers, fit a small block about ¾" thick into the top of each link block to prevent excessive travel of the valve, then fit two long blocks into the bottom end of the link. When you have occasion to reverse the engine you must transfer the two long blocks to the top of the link. You must either do this or be towed in. If one short arm breaks or gets bent very bad and you need the power of both sides, block one link as previously stated, but if not then disconnect one side, remove both eccentric straps and link if necessary; if not, tie top of it to the short arm of tumbling shaft, so the link cannot tip over, which would prevent reversing the engine. Should both arms break use same remedy as for broken tumbling shaft stands as just explained. If the top arm should break or become useless from any other cause, such as a lost key, if it cannot be used, it is sometimes possible to place a bar of iron or heavy block across the frame which will hold the short arms up in working position. In this event the bar and the arms should be securely fastened. If you find this remedy impossible fit a block into one link as previously stated. One block securely fastened will answer better than two, owing to the shifting positions of the links, which would cause the arms of the shaft to move up and down or spring. Care should always be taken not to let the link all the way down on the block as it will give increased travel, and may do some injury in the steam chest.

LINK HANDER, EITHER PIN OR LINK SADDLE.

Same remedy as for short arm of tumbling shaft.

LINK.

Disconnect one side, remove both eccentric straps and remove broken link or fasten top of it to tumbling shaft arm with bell cord. If both links should break prepare to be towed in.

EXTENSION ROD.

The engine truck sometimes bends or breaks the long extension rod which connects the link block and rocker arm on a ten-wheeled engine. Should this happen disconnect one side and remove the broken rod.

REACH ROD.

Same remedy as for top arm of tumbling shaft.

REVERSE LEVER.

Should the break occur in the reach rod hole or below it, then you must apply the same remedy as for top arm of tumbling shaft, or reach rod. Should the break occur above the reach rod connection you can usually hold it intact by fitting blocks inside the quadrant, if a solid quadrant, then any place you can secure a brace.

ROCKER ARM.

Should a top arm break disconnect that side. Should the bottom arm break, disconnect one side, remove the broken part of the rocker; if the link will then clear everything you can leave the eccentric straps up. But you must be certain that it will clear everything in both gears. If in doubt, remove the eccentric straps, then tie the top of the link to the short arm of the tumbling shaft to keep it from tipping over, which would prevent reversing the engine.

ROCKER PINS.

If the top should break replace it if you have an old one, if not then disconnect that side. If the bottom pin breaks it is sometimes possible to remove the top pin and turn the bottom

arm up high enough to clear the link, and then tie it up to the guide yoke. But you must be certain that it will clear the link when in full gear in each motion. If you are in doubt remove both eccentric straps, then tie the rocker forward or back to clear the link, and tie the top of the link to the short arm of the tumbling shaft to keep it from tipping over. You can use bell cord or wire for this purpose.

ROCKER BOX.

If it cannot be clamped or blocked secure then disconnect that side. If you can remove the rocker arm it will save taking down both eccentric straps, but if you cannot remove the rocker without difficulty then remove both eccentric straps and tie the top of the link to the short arm of the tumbling shaft, to prevent the link from tipping over.

GUIDES, BLOCKS OR BOLTS.

If any of the bolts break try and replace them. See that all nuts are tight, or they may be the cause of springing the piston. If a guide bar is broken badly disconnect one side.

GUIDE YOKE.

If the yoke is bent or broken and will not hold the guides secure disconnect one side.

DRIVING SPRINGS OR HANGERS.

With the heavy engines now in use road men are not expected to jack up the engine, and even if you have a small engine the quickest way is to use wedges on the rail, when possible to do so, as time is usually an important consideration; but it should be done carefully or you may break other springs or hangers or engine may leave the rail. If an eight-wheeled engine and a forward spring or hanger should break, place a fish plate or other piece of iron between the top of the back box and frame on the broken side, which will save raising the wheel that much higher and permit of a thinner wedge being used; now place a wedge on the rail and run the back wheel up on it, which will take the weight off the forward box. Now block solid with wood between the top of the forward box and the frame, remove spring saddle if necessary; now let engine down, remove the fish plate from the back box and run the main wheel up on the wedge, which will take the weight off the back box and relieve the equalizer. Now pry up the front end

of the equalizer and block it solid. Then let engine down, remove all loose parts and you are done. If the back spring or hanger is broken go through the same performance in the reversed manner by running the main wheel up on wedge first. If it is a mogul, or ten-wheeler, to raise the weight off the main wheel run the forward wheel up on the wedge, and to raise the weight off the forward pair, run the main wheel up on the wedge. If a mogul, and a forward spring or hanger is broken, you may have to remove both forward springs and block on top of both forward boxes, but if it is only a hanger, remember a chain may sometimes be used to replace it. When you block both forward boxes also block intermediate equalizer to truck. When the springs and equalizer are below the frame proceed in the same manner, then block or chain up the equalizer until level and remove or secure broken springs and hangers. When the spring hangers straddle the frame it is sometimes possible to block between the hanger and frame. Should the large spring below the frame and between the drivers break, block the top of both boxes, or block between both long hangers and the bottom of frame, and remove or secure broken spring and equalizers.

Should the small coil spring hanger break back of the rear drivers it may be possible to remove one of the small equalizers which ride the back box. If so, block on top of box; if not, and you cannot hold the spring hanger any other way, you may be able to chain the back end of small equalizers to frame; if not, you must let the frame ride the box, but run very slow.

EQUALIZERS.

Raise the engine the same as for a broken spring or hanger when possible to do so. If an equalizer on a standard eight-wheeled engine, block on top of one box and block up the loose end of the equalizer when possible the same as for a broken spring or hanger; if it cannot be used, block on top of both boxes. If below the frame do likewise, or chain it up. If forward equalizer on a ten-wheeled engine, block on top of the forward and main boxes, and block up forward end of back equalizer. If it is the cross equalizer on a mogul, block on top of both forward boxes and block on top of the back end of the long intermediate equalizer that goes to truck. If the intermediate equalizer breaks, block between the boiler and the cross equalizer. If it is the cross equalizer on a four-wheeled pony, block on top of both forward boxes. When this equalizer is below or between the frames it is sometimes possible to block between the hangers and the frame. If a small equalizer that rides the back box, block on top of the back box and chain

up the back end of the bottom equalizer. If it is a truck equalizer, block on top of truck boxes between the box and truck frame. Always remove or secure all loose parts.

EQUALIZER STANDS.

If the stand breaks then you must use the same remedy as for a broken equalizer, but if only the bolts break you may be able to find some old bolts to replace them, or take bolts off some other part of the engine that will fit, and the loss of which will not impair the working of the other parts.

ELIC BOLT ON MOGUL.

If an elic bolt should break you must block up between truck axle and the forward end of the long intermediate equalizer. A truck brass is very handy for this purpose.

ENGINE TRUCK SPRING OR HANGERS.

First raise the front end of the engine with jacks. If it is a four-wheeled truck pry up the frame on the broken side and block between the equalizers and the truck frame, close to the spring band, keeping it up level with the other side. If a mogul truck, then block between the top of the truck box and the truck frame.

CENTER CASTING.

If a truck center casting should break on a standard four-wheeled truck, jack up the front end of the engine; if you can find two short rails run these across the top of the truck equalizers and under the center casting; if you cannot find any block up both sides between the truck frame and cylinder saddle, but in this case run very slow when rounding curves, as engine won't track very well. If the top or male casting breaks you must block up the same way. If the pony truck center castings break, block between the truck frame and the engine frame on each side, but round curves slowly.

ENGINE TRUCK FRAME.

Raise weight of engine and place pieces of heavy iron between the equalizers and the truck frame, or a piece of rail may be chained to it for a splice.

ENGINE TRUCK WHEEL OR AXLE.

With a four-wheeled truck if a piece is broken out of the wheel, or the axle badly bent, it is sometimes possible to chain wheel, or place a timber across the rail in front of it, so it will slide to the nearest siding. If the axle is broken off outside of box, chain that corner of the truck to the engine frame, keeping it higher than the opposite side so the wheel will hug the rail; or remove the bad pair of wheels and chain that end of the truck to the engine frame, or proceed as follows: Chain broken axle to the engine frame, then jack up the front end of the engine until broken pair of wheels clear the rails; then block solid between the other truck boxes and truck frame, and between truck frame and engine frame, and on top of forward driving boxes. If a mogul truck remove broken wheels and chain truck up to the engine frame, and block on top of forward driving boxes. In either case proceed slowly.

DRIVING WHEELS AND TIRES.

Bad breaks of this kind often strip one side of the engine and sometimes disable it, but frequently the wheel only cracks, or the tire breaks but remains on the wheel. By running very slow and being careful the engine may be brought in, or at least to the nearest siding.

Main Wheel or Tire.—If it is a bad break disconnect broken side, remove all side rods and loose tire or other loose parts. If tire is broken run wheel up on wedges, or if wheel is broke raise axle with a jack, remove the oil cellar and drive a solid wooden block between the journal and pedestal brace. Then block under the spring saddle on top of the frame, and block between the frame and the top of the back box on that side; if this cannot be done without removing the saddles, then disconnect the springs and raise the engine high enough to allow for settling, so the broken wheel or tire will clear the rail. Then block solid on top of back box. If it is a blind tire the eccentric will prevent its leaving the rail; if it is an eight-wheeled engine also block between the truck equalizers and truck frame on both sides, as additional weight will be placed on the truck. Proceed slowly.

Forward Wheel or Tire.—Remove both side rods between forward and main wheels. If this cannot be done then remove all side rods. Remove both forward springs and saddles; if necessary block up broken wheel same as for main wheel, and

block on top of opposite box. If blind tire block up both forward wheels, raise front end of engine slightly, and block solid between engine frame and truck frame directly over the truck axle on each side. If it is a four-wheeled truck then block between truck equalizers and truck frame on both sides, let engine down, see that forward drivers clear the rail sufficiently and proceed slowly.

Back Wheel or Tire.—This is a more disagreeable break than a forward wheel, because the engine truck will support the forward end of the engine, while if it is a very heavy engine and it becomes necessary to block up both back wheels, a part of the weight must be transferred to the tender. This can sometimes be done by raising the back end and wedging between the chafing iron and the draw bar. If that cannot be done a piece of rail or heavy timber may be fastened on the deck with a chain and block under the end which projects out over the tender. When this break occurs remove both side rods between the back and main wheels; if you cannot then remove all side rods, remove all broken parts, and block up back wheel same as for main wheel and block on top of the main box on broken side. If tire cannot be removed and will not permit wheel to revolve, then block up both back wheels and block on top of both main boxes and throw weight on tender as previously explained.

DRIVING AXLES.

If an axle breaks off at the wheel, use same remedy as for broken wheel or tire. If a main axle should break or get badly bent between the boxes, prepare to be towed in. If a forward or rear axle should break or get badly bent between the boxes try and remove both wheels, or block them up same as for broken wheel or tire, and block engine accordingly.

DRIVING BRASS.

If a driving brass breaks and is cutting badly, run that wheel up on a thin wedge; then use an iron block between the top of frame and spring saddle, which will take the weight off that box.

WEDGE BOLT.

It is sometimes possible to screw the nut half way onto each part of the broken bolt and thereby hold it up in place. If this cannot be done, then with a wire try and fasten a nut under the wedge to hold it up.

THROTTLE ROD.

This is a very serious break, but more frequently the pins become disconnected with the throttle inside the boiler. If the throttle is open, or will open, you should not attempt to proceed with your train unless you have a good air brake. Keep the boiler pressure low, and the engine may be run in light by using the reverse lever for stopping. If the throttle will not open it is a good sign the pins are disconnected. The only remedy would be to raise the dome cap, but this is not required of road men, so prepare to be towed in.

POP OR WHISTLE BLOWN OUT.

Start both injectors immediately in order to retain as much water as possible. Kill or smother the fire, and as soon as sufficiently cool drive a soft wooden plug into the hole. See that you have sufficient water in the boiler, then fire up again, but keep the steam pressure low and proceed.

HAND HOLE PLATE OR PLUG BLOWN OUT.

Kill the fire immediately. Repack hand hole plate and replace it; if bolt is broken use some other bolt off engine, but see that it clears the eccentric strap. If a plug, make a soft wooden plug and drive it in tight. Refill the boiler, if near a water tank, fire up, keep steam pressure low and proceed. If you have no way to refill the boiler prepare to be towed in.

ENGINE FRAME.

If a bad break occurs between the main driving axle and the cylinders, and the break opens up very bad, you should use a little discretion—give up your train or disconnect that side as your judgment dictates—and under no circumstances let another engine pull on you. Report a broken frame as soon as possible.

DRAW BAR.

If the engine has safety chains they will hold the tank, but not always a heavy train. If the engine is not equipped with safety chains then secure a chain from the tank box or caboose and chain the tank to the deck.

WATER GLASS.

Shut off both cocks and use gauge cocks, which should be frequently used even if you have a water glass.

BOTH INJECTORS FAIL TO WORK.

Kill the fire and prepare to be towed in, but you should use every effort to keep them working. See chapter on "Injectors."

LUBRICATOR WON'T WORK.

Shut off steam, disconnect oil pipes and oil through the pipe frequently.

Accidents With Compound Engines.

BALDWIN COMPOUND.

VALVE STEM.

Clamp valve in center of seat to cover all steam ports, remove main rod on that side and clamp cross-head secure.

HIGH PRESSURE PISTON OR CYLINDER HEAD.

Remove the broken piston and clamp heavy board on end of cylinder, making steam-tight joint. The steam will then pass direct to the low pressure cylinder, making it high pressure.

LOW PRESSURE PISTON OR CYLINDER HEAD.

If piston or head is broken you may still proceed using high pressure cylinder; the steam will then exhaust through broken cylinder head instead of through stack, so if the escaping steam obstructs your view you had better disconnect that side.

MAIN ROD.

Clamp valve in center of seat to cover all ports, remove broken rod and clamp cross-head secure—run in with one side. If your engine has direct motion, and valve stem is fastened to the cross-head, clamp cross-head secure in the center of the guides.

EQUALIZING VALVE.

If the small equalizing valve in the end of the main steam valve is broken or removed it will convert that side into a high pressure engine, the work being done by the low pressure cylinder; the high pressure piston then would be approximately balanced. A head broken out of the main steam valve would have the same effect.

SCHENECTADY COMPOUND.

MAIN ROD HIGH PRESSURE.

Remove broken rod, blocking cross-head at front end of the guides. Clamp the high pressure valve forward to clear the exhaust port; the steam will then pass through the exhaust port on the high pressure side into the receiver, thence to the low pressure steam chest. The low pressure cylinder then acts as a high pressure engine. Open the throttle valve moderately on account of the large area of low pressure cylinder.

MAIN ROD LOW PRESSURE.

Remove broken rod, secure cross-head at back end of guides; clamp the low pressure valve back far enough to clear exhaust port. Exhaust steam can then pass through low pressure cylinder and out through the stack.

VALVE STEM ON EITHER SIDE.

The same remedy as for a main rod on that side; also remove the main rod and secure it as previously instructed.

INTERCEPTING VALVE.

Should the intercepting valve become disabled, and you can clamp the poppet valve open, do so; if not, then remove the back head from the intercepting valve steam cylinder, and push the piston forward, putting in a block to hold it in that position; then put on the head, which will prevent the steam in the receiver closing the poppet valve. The same may be done with the small piston which moves the valve, admitting steam to the intercepting valve steam cylinder; this will also prevent closing the poppet. Live steam would then be admitted to both cylinders for starting.

RHODE ISLAND COMPOUND.

MAIN ROD LOW PRESSURE.

Remove the broken rod and clamp the cross-head at the back end of the guides. Clamp the low pressure valve central on its seat to cover all ports; open the exhaust valve in the receiver to the exhaust nozzle and proceed with one side, as with simple engine.

MAIN ROD HIGH PRESSURE.

Remove all broken rod and secure the cross-head at the back end of the guides; clamp valve in center of ports, using low pressure as a high pressure cylinder. Open throttle gradually on account of the large area of the low pressure cylinder.

VALVE STEMS, EITHER SIDE.

The same as for broken main rods.

INTERCEPTING VALVE.

If the piston head of the intercepting valve which closes the receiver to the low pressure steam chest gets broken or cracked, the engine may be run without using live steam in the low pressure cylinder by removing the back head of the intercepting valve cylinder, and moving the valve to the compounding position and blocking it secure. The hole in the intercepting valve which would allow live steam to escape from the low pressure steam chest to the atmosphere prevents the exhaust valve in the receiver being opened and engine run as a high pressure engine.

RECEIVER.

In case of a broken or cracked receiver, open the exhaust in the receiver and run as a high pressure engine.

PITTSBURG COMPOUND.

MAIN ROD LOW PRESSURE.

Remove the broken rod, block cross-head at back end of guides, clamp low pressure valve in the center of its seat, covering the ports on that side; turn the intercepting valve to open the exhaust from the high pressure cylinder direct to the stack.

MAIN ROD HIGH PRESSURE.

Remove broken rod and clamp cross-head at back end of guides; clamp the high pressure valve in the center of its seat to cover all ports on that side; pull back the intercepting valve which opens the reducing valve and admits steam to the receiver and low pressure steam chest. Run in with one side.

VALVE STEM—EITHER SIDE.

The same as for main rod on that side.

REDUCING VALVE.

Should the reducing valve get broken, the engine may be run as a high pressure engine by putting the intercepting valve in the non-compound position.

INTERCEPTING VALVE.

Should the front head of the intercepting valve get broken or cracked live steam would escape into the atmosphere when in the non-compounding position, which would cause the engine to be weak on that side; if the crack was very large the intercepting valve should be moved forward until the back head covered the exhaust port to the stack. The live steam from the reducing valve could then pass to the low pressure steam chest through the receiver. After starting the intercepting valve can be placed in compounding position and run as a compound.

BROOKS COMPOUND.

MAIN ROD LOW PRESSURE.

Remove the broken rod and block the cross-head securely at the back end of the guides. Move the low pressure valve back to clear the exhaust port on that side and clamp it there.

MAIN ROD HIGH PRESSURE.

Disconnect this side the same as for a simple engine and run in on one side. Steam will pass through the reducing and intercepting valve to low pressure cylinder.

VALVE ROD—EITHER SIDE.

Same remedy as for main rod on same side.

INTERCEPTING VALVE.

Should the intercepting valve get broken so as to leave an opening to the receiver, use a blind gasket at the joint where the small steam pipe joint joins the intercepting valve, which will prevent live steam getting into the receiver.

REDUCING VALVE.

Same remedy as for intercepting valve.

BROOKS TANDEM COMPOUND.

MAIN ROD.

Remove the broken rod and fasten the cross-head secure; set both valves central on their seats and fasten them there. Run the engine in on one side.

VALVE ROD.

The same remedy as for main rod.

FRONT HEAD OF HIGH PRESSURE CYLINDER.

When this break occurs the quickest remedy would be to disconnect one side, as previously stated; but you could retain the use of the low pressure cylinder by taking off the front head of the valve chamber, and disconnect the high pressure valve, then block the valve in the center of its seat to cover the ports. The low pressure cylinder will then act as a high pressure engine on that side.

BROKEN RECEIVER.

Place a blind gasket in the joint where the steam pipe joins the high pressure steam chest; disconnect the main rod and block the cross-head secure.

REVERSING ARM BETWEEN THE VALVES.

Remove the main rod and block cross-head; clamp low pressure valve central over its ports with the valve stem; remove the front end of the high pressure valve chamber and block valve in central position and put the head back on. Whenever you can do so, set both valves central on their seats; when this cannot be done, try to put a blind gasket in the steam pipe joint, which will prevent steam from getting into the valves or cylinders.

The Lewis Valve Gear.

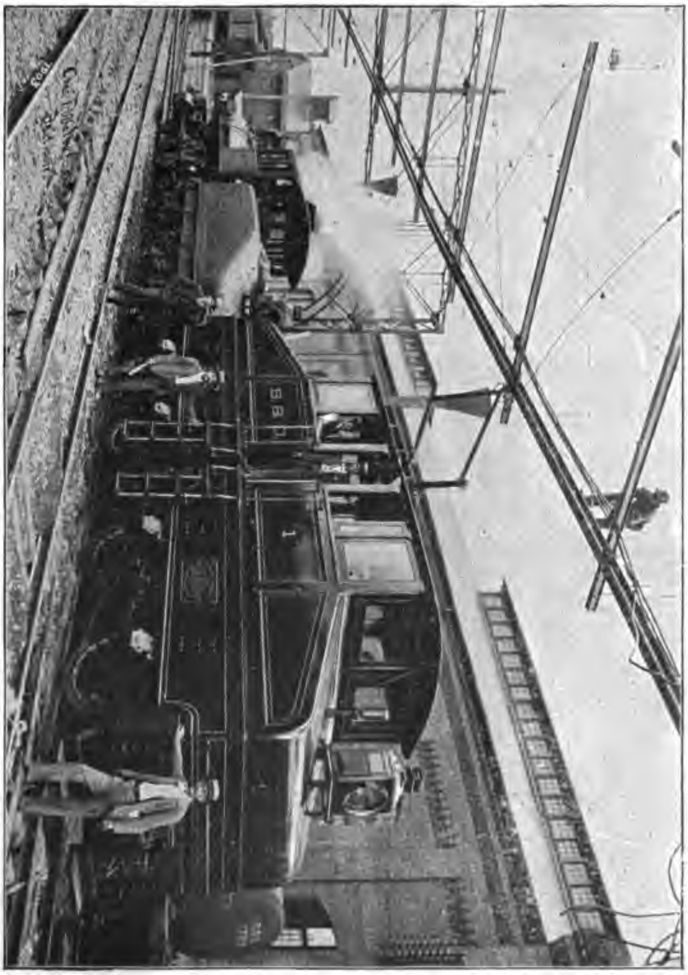
This valve gear is a recent production which dispenses with eccentrics, links, rockers, etc., and derives its motion from the cross-head, and is so constructed that the lap and lead movement on one side is controlled by the cross-head on the same side, while increased travel to the valve is conveyed from the opposite cross-head. This valve gear is practically the duplex pump movement with a reversible cut-off attachment added, with this motion the valves are usually given 3-16″ lead, which is constant. Owing to its compactness and close proximity to the steam chests, it necessarily diminishes the amount of lost motion, which is often an important factor on ten-wheeled engines, causing the valves to "sound out of square."

While this gear has some good qualities, it was given a fair trial on the Wabash, Vandalia and Illinois Central Railways, where it failed to demonstrate its superiority over the old reliable shifting link; it was therefore removed, and we hear that at present it is being tried on some of the Western roads.

MODERN LOCOMOTIVES.

ELECTRIC LOCOMOTIVE, BALTIMORE & OHIO R. R.

With the view principally of abating the nuisance of smoke and gases arising from steam locomotives in drawing passenger trains through long tunnels, the B. & O. R. R., with the cooperation of the General Electric Co., has brought into service this powerful electric locomotive to use in their tunnel under the city of Baltimore, Md. It weighs 96 tons, the whole weight resting on the drivers, which are 62 inches in diameter; the wheel base of each truck is 6 feet 10 inches, and the length over all 35 feet; height, 14 feet 3 inches. It has a motor on each axle, each motor being 360 H. P. The trolley support shown is diamond shape, and compressible, contracting and expanding as may be necessary, and leaning to one side or the other of the overhead conductor. The tunnel where this engine is used is 7,339 feet long, with a grade of 8 degrees; the total haulage by electric traction is 3 miles. Passenger trains are taken through the tunnel at a speed of 35 miles per hour. Under a test this engine developed a speed of almost 60 miles per hour; but its power is more wonderful than its speed. A test made October 6, 1895, has added to the list of extraordinary performances of this locomotive, the character of which is heightened by the fact that the train which it moved measured 1,800 feet in length and weighed 1,900 tons, and was started from rest in the tunnel. The train consisted of 43 loaded cars and 3 locomotives. In starting, it is said, not a sputter, spark or slip of the wheels occurred. The draw bar pull is given at 60,000 pounds; and the train was quickly brought to a speed of 12 miles per hour when the draw-bar stress was but 40,000 pounds. This locomotive has been in use about one year.



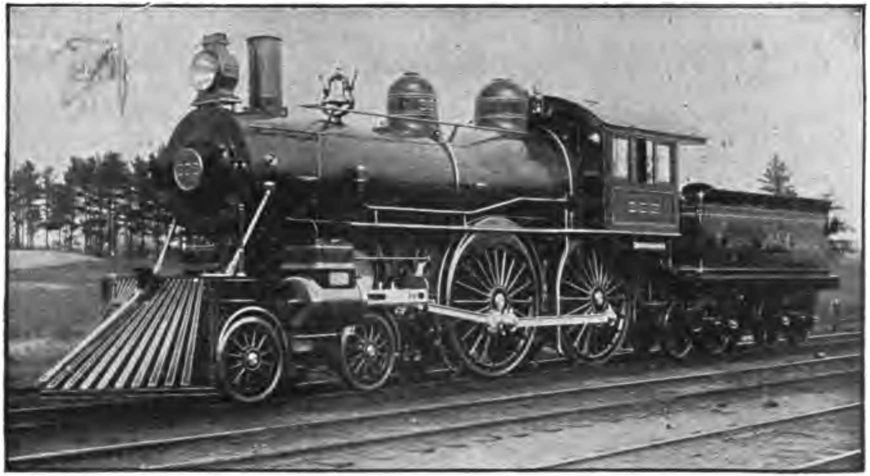
ELECTRIC LOCOMOTIVE, BALTIMORE & OHIO RAILWAY.

ENGINE NO. 999, NEW YORK CENTRAL & HUDSON RIVER R. R.

This engine is no doubt the fastest locomotive in the world. It was designed to run 100 miles per hour by Mr. Wm. Buchanan, Supt. M. P. of the N. Y. C. & H. R. R. R., and built by that company. It has cylinders 19x24 inches, with drivers 87 inches in diameter, and weighs, in working order, 102 tons. It was used to haul the Exposition Flyer during the World's Fair in 1893, when it became famous for its extraordinary fast runs, an abstract of which is given on page 294. This engine has a speed indicator and recorder which is driven from the truck wheels to eliminate slippage.

ENGINE NO. 1 NEW YORK, ONTARIO & WESTERN RY.

This engine was designed and built in order to demonstrate whether an engine of these dimensions and weight would give better results than a compound engine, also whether an engine of this weight in passenger service with cylinders 17x24" and a constant boiler pressure of 180 pounds would not be better than one with 18x24" cylinders, and lagging for steam on heavy grades. It was intended, also, to demonstrate whether such an engine could not be run at a much reduced cost of fuel. This engine has been in constant service since November 23, 1895, and has met the highest expectations of its designer, Mr. George W. West, Supt. M. P. of the New York, Ontario & Western railway. It has shown a surprisingly good fuel record, as it is run opposite one of their best anthracite coal burners with 18x24" cylinders, and during a test of 14 days when every pound of coal used by both engines was weighed; this engine hauled the same train 2,020 miles at a cost of 3¾ cents per engine mile, while the other engine's fuel cost 6¼ cents per engine mile; this is considered as near perfect as an engine can be built for burning cheap fuel. As may be seen by the illustration, it is of the eight-wheeled type, the rear driving axles being under the fire box. The fire box is of the Wooten type, and the cab is over the center of the boiler and entered from the front, as is usual in this arrangement. The boiler is supplied by two No. 8 Monitor injectors. The Smith triple expansion exhaust pipe is used, also the Leach track sanding apparatus, and Nathan triple slight feed lubricator.



Engine No. 999, New York Central & Hudson River R. R.

Dimensions, Weight, Etc.

Total weight of engine in working order ....110,000 lbs.
Total weight on drivers.......... 76,000 lbs.
Total weight of tender with fuel and water .... 80,000 lbs.
Total weight of engine and tender in working order..................190,000 lbs.
Driving wheel base................8 ft. 6 in.
Total wheel base of engine......23 ft. 1 in.
Total wheel base of engine and tender ....47 ft. 2 in.
Height from rail to top of stack.14 ft. 11 in.
Diameter of driving wheels outside of tires...............................68 in.
Cylinders ....17x24 in.

Steam ports......................$1\frac{1}{2}$x$15\frac{1}{2}$ in.
Exhaust ports...................., 3x$15\frac{1}{2}$ in.
Kind of valves........Richardson Balance
Outside lap..........................13-16 in.
Lead .... 1-32 in.
Maximum travel of valve...........$5\frac{3}{4}$ in.
Number of boiler tubes..................197
Heating surface fire box..........130 sq. ft.
Total heating surface............1,166 sq. ft.
Grate area......................... 63 sq. ft.
Fire box, width 7 ft.; length 9. ft. ....Wootten Type
Boiler, inside diam. smallest ring....55 in.
Maximum boiler pressure...........180 lbs.
Exhaust pipe......Smith triple expansion

Engine No. 1, New York, Ontario & Western Ry.

Cooke.

Dimensions, Weight, Etc.

Gauge of track ....4 ft. 8½ in.
Weight in working order........120,000 lbs.
Weight on drivers..................75,500 lbs.
Weight of tender empty..........38,800 lbs.
Driving wheel base................8 ft. 6 in.
Total wheel base of engine......23 ft. 5 in.
Diameter of driving wheels outside
of tire ....69 in.
Driving journals......................8x11 in.
Cylinders ....19 in. diam. 24-in stroke
Steam ports ....1¼x18 in.
Exhaust ports ....2¾x18 in.
Bridges ....1⅛ in.
Valves ....Richardson Balance
Valves, greatest travel................5½ in.
Valves, outside lap....................⅞ in.
Valves inside lap...............line and line
Valves, lead in full gear...........1-64 in.

Exhaust nozzles 4½x4¾x5 .in..Single high
Boiler, style extended wagon top,
sheet ....9-16 in.x11-16 in.
Boiler, outside diam. of first ring....62 in.
Boiler, working pressure............190 in.
Fire box, heating surface........155 sq. ft.
Total heating surface............2,067 sq. ft.
Grate area . ...26.96 sq. ft.
Boiler tubes, diam. 2 in........number 320
Tender frame...7 in.x3½ in.x1 in. angle iron
Tender, water capacity ....4,000 gal.
Tender, coal capacity..................8 tons
Brakes, American equalized on drivers operated by air
Brakes, Westinghouse automatic on tender
Westinghouse air signal
Leach track sander

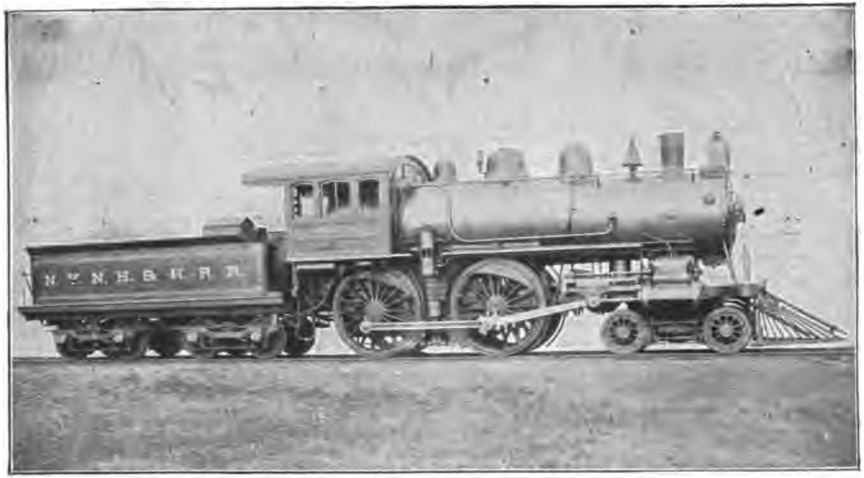
Engine No. 211, Boston & Albany R. R.

Schenectady.

Dimensions, Weight, Etc.

Cylinders ....20 in. diam. 24-in. stroke
Drivers ....78 in. diam.
Driving wheel base................9 ft. 0 in.
Total wheel base of engine....24 ft. 3 in.
Total wheel base of engine and tender ....49 ft. ½ in.
Total weight in working order..133,000 lbs.
Total weight on drivers..........86,000 lbs.
Total weight on engine truck....47,000 lbs.
Total weight of tender...........80,000 lbs.
Tank capacity.....................4,000 gals.
Boiler, steel extended wagon top pattern, sheet.................11-16 in. thick
Diam. of boiler at smoke box......62 in.
Boiler tubes 2 in. outside diam....No. 312

Fire box, sheet ⅜ in. thick, dimensions ....114 in. long 42¼ in. wide
Working pressure....................190 lbs.
Pistons ....Steel
Cross heads........................Cast steel
Guides.................Cast iron gun metal
Axles.........................Hammered iron
Journals ....8 in. diam. 11½ in. long
Crank pins ....Steel
Driving brasses and rod brasses.... ....Damascus bronze
Engine furnished with fire brick arch
Tender frame....................White oak
Cylinder head and steam chest castings ....Pressed steel



Engine No. 254, New York, New Haven & Hartford R. R.

Rhode Island.

Dimensions, Weight, Etc.

Gauge of track	4 ft. 8½ in.
Total weight of engine	150,000 lbs.
Total weight on drivers	110,000 lbs.
Wheel base, drivers	13 ft. 6 in.
Wheel base, total eng.	24 ft. 9½ in.
Wheel base, total eng. and tender	52 ft. 2 in.
Height of stack	15 ft. 9 in.
Heating surface, fire box	187.5 ft.
Heating surface, total	2,309 ft.
Grate area	35.35 ft.
Boiler tubes, outside diam. 2¼	No. 261
Driving wheels	Diam. 72 in.
Driving journals	8½x10 in.
Cylinders, diam. 20 in.	Stroke 24 in.
Steam ports	1⅝x20 in.
Exhaust ports	3¼x20 in.
Bridge	Width 1½ in.
Valves	Allen-Richardson
Valves, maximum travel	6 in.
Valves, outside lap	1⅛ in.
Valves, inside clearance	1-16 in.
Valves, lead in full gear	1-16 in.
Nozzles	Single high
Boiler	Extended wagon top sheet 9-16x⅝
Boiler, diam. of boiler outside first course	66 in.
Tender frame	9 in. steel channels
Capacity of tender—water	4,200 gals.
Capacity of tender--coal	6 tons

Engine No. 101, Savannah, Florida & Western Ry.

Rogers.

Dimensions, Weight, Etc.

Cylinders	17x24 in.	Valves	Allen-Richardson
Diameter of driving wheels	68 in.	Outside lap	1 in.
Total weight	113,500 lbs.	Inside lap	3-32 in.
Weight on drivers	88,500 lbs.	Lead in full gear	1-64 in.
Diameter shell of boiler	52 in.	Maximum travel of valves	6⅛ in.
Total heating surface	1,603 sq. ft.	Working steam pressure	180 lbs.
Grate area	28 sq. ft.	Nozzles	High double

Engine No. 564, Lake Shore & Michigan Southern Ry.

Brooks.

Record 92.3 Miles per Hour.

Dimensions, Weight, Etc.

Total weight of engine in working order ....138,000 lbs.
Total weight on front drivers.. 39,600 lbs.
Total weight on main drivers... 46,600 lbs.
Total weight on trailers......... 31,800 lbs.
Total weight of tender with fuel and water .... 72,300 lbs.
Total weight of engine and tender in working order....224,300 lbs.
Driving wheel base.............. 7 ft. 6 in.
Total wheel base of engine......24 ft. 3 in.
Total wheel base of engine and tender ....49 ft. 11¼ in.
Total length of engine and tender ....63 ft. 5 in.
Height from rail to top of stack ....14 ft. 4½ in.
Diameter of driving wheels outside of tires .... 84¼ in.
Driving wheel centres...........Cast steel

Diameter of cylinders.............19x26 in.
Size of steam ports...............1¾x21 in.
Size of exhaust ports...............3x25 in.
Kind of valves.................Piston type
Maximum travel of valve.............6 in.
Outside lap of valve....................1 in.
Inside clearance ....¼ in. each end
Lead in full gear.....................1-32 in.
Number of boiler tubes..................210
Fire box—5 ft. 2¼ in. and 4 ft. 9¾ in. high—5 ft. 0 in. wide—8 ft. 10¾ in. long
Heating surface of fire box....187.4 sq. ft.
Total heating surface........1,580.12 sq. ft.
Grate area........................44.47 sq. ft.
Diameter of boiler inside smallest ring ....57⅜ in.
Maximum steam pressure...........200 lbs.
Tank frame..............................Steel
Tank capacity, water..........42,000 gallons
Tank capacity, coal....................7 tons

Engine No. 590, Chicago, Burlington & Quincy R. R.

Baldwin.

Record 88 Miles per Hour.

ENGINE NO. 590 CHICAGO, BURLINGTON & QUINCY R. R.

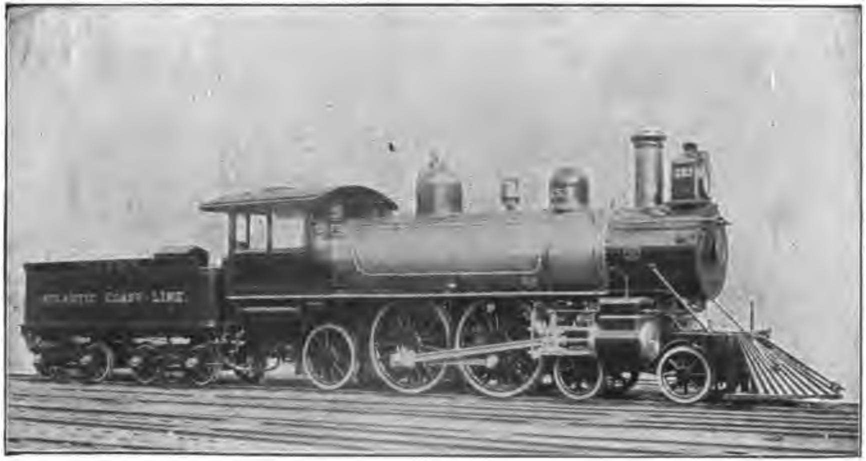
As may be seen by the illustration and a perusal of its dimensions, this engine embraces a radical departure from the well established American practice of locomotive construction. It favors English practice throughout and has their typical six-wheeled tender. It is of the Columbia type, designed by the Baldwin Locomotive Works in 1891, and built during September, 1895, from special specifications by Mr. George W. Rhodes, Supt. M. P. of the Chicago, Burlington & Quincy railway, to haul their fast mail trains at a speed of 80 miles per hour. It is the first single expansion locomotive of this type built in America, which created considerable interest in the mechanical world. While this engine has made some remarkable runs, it has not given entire satisfaction. We have given its best record for time on page 294, and its dimensions on page 279. It is equipped with a speed indicator and recorder, and often develops an enormous speed for short distances.

ENGINE NO. 10 ATLANTIC COAST LINE.

This special type of locomotive was designed especially for the Atlantic Coast Line to haul the fast "Florida Special" passenger trains in the through service between New York and Florida. The performance required of these engines was to haul a train of ten cars, composed of Pullman, baggage, and express, and ordinary coaches, aggregating about 400 gross tons of 2,240 pounds, at a speed of 40 miles per hour, over grades of 32 feet per mile. While this service did not require great adhesion, it necessitated unusually large heating surface in order to maintain the required speed. The "ten-wheeled" type was therefore adopted in order to obtain adequate boiler capacity without excessive weight per axle, but as the adhesion of the rear pair of driving wheels was not required, a pair of trailing wheels of small diameter was substituted. This made it possible to use a large, square fire-box, placed on top of the frames. In addition to the large boiler capacity and fire-box heating surface thus obtained, this type of engine has other advantages. The driving-wheels are coupled closely together, affording a short parallel rod, an important consideration in high speed service, while at the same time the main rod is of ample length. The coupled and trailing wheels are equalized together, giving the engine a smooth motion when running at high speed. A foot-plate back of the fire-box affords ample convenience for the engineer and firemen, and being located also back of the driving-wheels, the motion of the latter is not felt, and the men are out of danger in the event of the breaking of coupling rods. The engines are performing satisfactorily the service required.

Dimensions, Weight, Etc.

Cylinders	19x24 in.	Flues, diameter	2 in.
Driving wheels	72 in.	Flues, length	14 ft. 3 in.
Driving journals	8x10 in.	Heating surface, flues	1,913.7 sq. ft.
Trailing wheels	42 in.	Heating surface, fire-box	133.5 sq. ft.
Trailing journals	6½x10 in.	Heating surface, total	2,047.2 sq. ft.
Truck wheels	36 in.	Grate area	26.2 sq. ft.
Truck journals	5x10 in.	Weight on truck wheels	25,200 lbs.
Total wheel base	23 ft. 10 in.	Weight on driving wheels	77,640 lbs.
Rigid wheel base	12 ft. 6 in.	Weight on trailing wheels	22,300 lbs.
Driving wheel base	6 ft. 3 in.	Weight in working order, total	125,140 lbs.
Boiler, diameter	60 in.	Tender, capacity	3,600 gallons
Fire-box	90x42 in.	Tender wheels, diameter	33 in.
Flues, number	258	Tender journals	4¼x8 in.



Engine No. 153, Atlantic Coast Line.

Baldwin.

Engine No. 340, Delaware & Hudson Canal Co.

Dickson.

Cylinders 18x24", Driving Wheels 62", Weight 85,000 lbs.

Compound Locomotives.

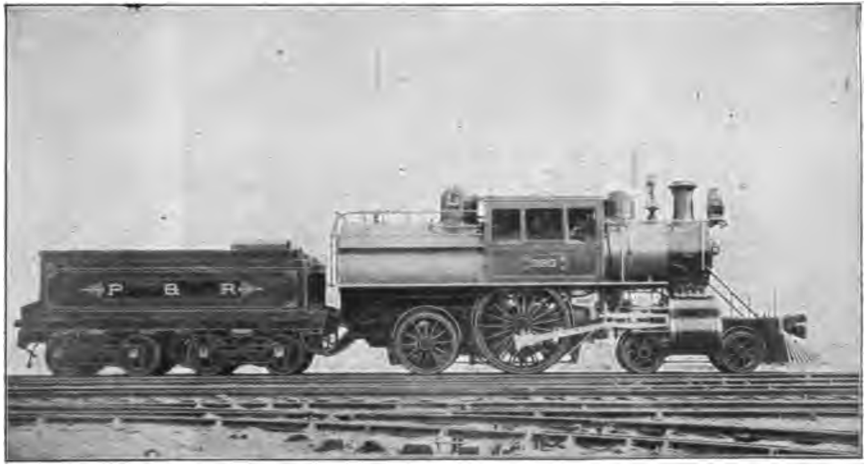
Although compound locomotives have been in use many years, a great diversity of opinion exists at the present day regarding their merits; while they have given excellent results in some cases, on many roads where they were given a trial the additional expense for repairs largely offset their economy on fuel, and their use has been discontinued. While they possess many disadvantages under the present mode of construction, they embrace the correct principle of economy, and will, no doubt, when improved eventually become the established type of the American locomotive. The object of compounding is to use the same steam for power in more than one cylinder before release; the steam from a high pressure cylinder being exhausted into a low pressure one. Several systems of compounding are in use, the Vauclain, the Tandem and the Cross compound being the principal forms used in this country. The Vauclain system has two cylinders on each side, one a high and one a low pressure, one being above the other as shown by the illustration on page 287. The Tandem compound also has two cylinders on each side, the axis of each cylinder being in a horizontal line. The Cross compound has a high pressure cylinder on one side and a low pressure one on the opposite side, as shown by the illustration on page 289. The cylinders on this system of compounding are made of different sizes in order to equalize the power on each side of the engine; a small cylinder with a high pressure in it will exert as much force as a large cylinder with a less pressure, and they are proportioned to each other in order to obtain an equal amount of power on each side of the engine.

With the other two forms of compounding the power is equal on each side and the cylinders are proportioned to each other to give the best results, the low pressure usually having about three times the area of the high pressure cylinder.

Some of the Cross compound engines have a separate exhaust for each cylinder; an intercepting valve is used and it can be worked simple when required, or in case of a break down on either side. When working simple the pressure of live steam in the low pressure cylinder is controlled by an automatic regulating valve and cannot exceed one-half the boiler pressure. Standard link motion is used on all of these engines, so the mechanic who understands other locomotives will experience no difficulty when working upon compound engines.

ENGINE NO. 385 PHILADELPHIA & READING RAILROAD.

This illustration represents another radical departure from well established American practice of locomotive construction. Single drivers have been used in this country before, but they were never so popular as in England, and this is the first compound single driver built in America. This engine was built by the Baldwin Locomotive Works in June, 1895, from designs by Mr. L. B. Paxon, Supt. M. P. of the Philadelphia & Reading railway, who had previously experimented by removing the side rods from an eight-wheeled engine; by increasing the weight on the single pair of drivers it was his intention to secure sufficient adhesion to start an ordinary train, while the advantages gained by dispensing with the friction of an extra pair of wheels and the side rods would add materially to its speed. This engine has been in service since July 3, 1895, hauling their fast trains between New York and Philadelphia, and she has given such good results that her double was ordered and built and is now sharing honors with the 385. This engine has drivers 84¼″ in diameter with a trailer 54¼″ in diameter. The cylinders are of the Vauclain system of compounding and are 13″ and 22″ in diameter with a 26″ stroke. The boiler is of the Wooten type, 56″ in diameter at smallest ring; made of ⅝″ steel and carries a working pressure of 200 pounds. The fire box is 114x96″ and has 324 tubes 1½″ in diameter. Total weight of engine, 115,000 pounds, with 48,000 pounds on the drivers. The driving journals are 8½x12″. From the position of the cab the reverse lever is attached direct to the lifting shaft. The tank is equipped with a water scoop. This engine has made several extraordinarily fast runs, which are given on page 295, and we believe that this class of engines is destined to become a distinctive and popular type of the American locomotive.



Engine No. 385, Philadelphia & Reading R. R.,
Single Driver,

Baldwin-Compound.

Record 87.5 Miles per Hour.

Dimensions, Weight, Etc.

Total weight of engine in working order ....112,550 lbs.
Total weight on drivers.......... 72,000 lbs.
Total weight on tender...........30,600 lbs.
Total weight on tender with fuel and water .... 73,770 lbs.
Driving wheel base of engine..........8 ft.
Total wheel base of engine......22 ft. 6 in.
Total wheel base of engine and tender ....47 ft. ½ in.
Total length of engine and tender ....57 ft. 9¼ in.
Height from rail to top of stack......15 ft.
Diameter of driving wheels outside of tyres..........72 in.
Diameter of cylinder—high pressure ....19x26 in.
Diameter of cylinder—low pressure ....29x26 in.
Size of steam ports—high pressure ....1⅜x16 in.
Size of steam ports—low pressure.1¾x18 in.
Size of exhaust ports—high pressure. ....2½x16 in.
Size of exhaust ports—low pressure ....3¼x18 in.
Valves ....Richardson Balance
Travel of valve—high pressure...... 5 in.
Travel of valve—low pressure........ 6 in.
Outside lap of valve—high pressure.. 1 in.
Outside lap of valve—low pressure... ⅞ in.
Inside clearance—high pressure....5-16 in.
Inside clearance—low pressure...... ⅛ in.
Lead in full gear—high pressure....1-32 in.
Lead in full gear—low pressure....1-16 in.
Number of boiler tubes..........240
Heating surface of fire-box...... 123.17 ft.
Total heating surface..........1,474.05 ft.
Grate area..........26.8 sq. ft.
Diameter of boiler, smallest ring......58 in.
Diameter of boiler, back head.........67 in.
Steam pressure..........180 lbs.
Single nozzle—four sizes, 4¾ in. 5 in. 5¼ in. 5½ in.

Engine No. 1452, Eight-Wheeled Passenger.

Pittsburg-Compound.

Dimensions, Weight, Etc.

Gauge of track....................4 ft. 8½ in.
Total weight of engine in working order ....143,000 lbs.
Total weight on drivers...........127,000 lbs.
Wheel base, total.................23 ft. 5 in.
Wheel base, driving...............15 ft. 8 in.
Driving wheels, diam...................50 in.
Driving journals ....7¾x8 7-16 in.
Main crank pin journal..........6½x6 in.
Cylinders—high pressure............21x24 in.
Cylinders—low pressure ....33x24 in.
Steam ports—high pressure......1¼x23 in.
Steam ports—low pressure........1½x23 in.
Exhaust ports—high pressure......3x23 in.
Exhaust ports—low pressure....3½x23 in.

Valves..................Richardson Balance
Valves, travel—H. P. 5½ in.—L. P. 6 in.
Valves, outside lap—H. P. 1.15-16 in.—L. P..................................15-16 in.
Valves, inside clearance—H. P. ⅜ in.—L. P..................................5-16 in.
Boiler, diam. of barrel at front sheet....................................62 in.
Boiler—working pressure ....200 lbs.
Boiler tubes, outside diam. 2 in.....No. 281
Heating surface, fire box........228 sq. ft.
Heating surface, total..........1,972 sq. ft.
Grate area ....28.18 sq. ft.
Tender frame.....................Angle iron
Tender, capacity six tons......4,000 gallons

Engine No. 100, Chesapeake & Ohio Ry.

Richmond-Compound.

BALDWIN COMPOUND.

This is the Vauclain system of compounding, having both high and low pressure cylinders on each side, the steam from the high pressure cylinders exhausting into the low pressure cylinders on the same side and thence out through the stack, making each side independent of the other, with an equal pressure exerted on each side, one cylinder being above the other, with both pistons fastened to the same crosshead. On engines that stand high above the rail the high pressure cylinder is above the low pressure one, while on engines that are very low the high pressure cylinder is placed below to clear the rail.

SCHENECTADY COMPOUND.

This system has a high pressure cylinder on one side and a low pressure on the opposite side, with the Pitkin starting gear and intercepting valve; when starting steam is admitted to both cylinders, which automatically change to compound after starting.

RHODE ISLAND COMPOUND.

This style of compounding has a high pressure cylinder on one side and a low pressure cylinder on the other. The intercepting valve used is a patent of the Rhode Island Locomotive Works. The engine starts with steam in both cylinders and automatically changes to a compound at any desired receiver pressure. The engine may be worked simple or compound, as desired, by simply moving a lever in the cab.

PITTSBURG COMPOUND.

This system is of the two-cylinder type, with the Colvin starting valve. It can be worked as a compound, or steam can be admitted directly into the low pressure cylinder, as desired. When both cylinders are using steam direct from the boiler a reducing valve is used on the low pressure side to equalize the force exerted in the two cylinders.

BROOKS COMPOUND.

This is a two-cylinder compound, about the only difference between this and other cross compounds being a combination reducing and intercepting valve invented by Mr. John Player, Mechanical Engineer of the Brooks Locomotive Works. With this valve steam is admitted to both cylinders, and the steam from the high pressure cylinder is exhausted into a closed re-

ceiver until the back pressure in the receiver equals that of the steam being admitted into the low pressure cylinder, when the intercepting valve opens, which closes the reducing valve, thus cutting off the direct supply of steam to the low pressure cylinder.

BROOKS TANDEM COMPOUND.

The word tandem means "one after another," and as applied to locomotive cylinders it means two cylinders whose centers are in the same horizontal line, having two cylinders on each side of the locomotive, one being a high pressure and the other a low pressure cylinder. Very few compound engines of this style are in use in this country. Those built by the Brooks Locomotive Works contain the patents of Mr. J. Player, M. E., of those works.

FAST RUNS.

The greatest speed attained by a locomotive, of which there is any record, was made by engine No. 999 of the New York Central & Hudson River Railroad Co., on May 9, 1893, having covered five consecutive miles at the rate of 102.8 miles per hour. This remarkable performance was made with the Empire State Express, a train consisting of four heavy parlor cars, on a descending grade of 20 feet per mile. It is claimed she covered a single mile at the rate of 112½ miles per hour, but we can find no official record of such performance.

On May 19, 1893, engine No. 903, a double of the 999, covered the same ground, with the same train, at the rate of 100 miles per hour.

Previous to that time there were five records running from 87.8 to 97.3 miles per hour, on the Philadelphia & Reading, and the Central Railroad of New Jersey, which were made in 1890, 1891 and 1892; three of these records, including the highest one, were made by engine 385, a Baldwin four-cylinder compound.

On October 24, 1895, engine No. 564, of the Lake Shore & Michigan Southern Ry. Co., run from Erie, Pa., to Buffalo, N. Y., a distance of 86 miles, at an average speed of 72.91 miles per hour, having covered a single mile at the rate of 92.3 miles per hour.

On November 11, 1895, engine No. 590 of the Chicago, Burlington & Quincy Ry. Co. made a run with six heavy mail cars from Galesburg, Ill., to Mendota, Ill., a distance of 80 miles, at an average speed of 67.6 miles per hour, covering a single mile at the rate of 88 miles per hour.

On April 21, 1895, Pennsylvania Railroad Engine No. 1658, "Class P," pulled a combination baggage car from Camden, N. J., to Atlantic City, N. J., a distance of 58.3 miles, at an average speed of 76.46 miles per hour; while from Liberty Park to Absecon, a distance of 49.8 miles, the speed averaged 79.7 miles per hour; from Berlin to Absecon. 35.6 miles, it averaged 82.9 miles per hour, and from Winslow Junction to Absecon, a distance of 24.9 miles, the speed was 83 miles per hour; the fastest single mile being made at the rate of 87.8 miles per hour.

On May 7, 1894, engine No. 655 of the Lehigh Valley R. R. Co. covered a single mile at the rate of 82½ miles per hour. This engine has cylinders 20x25", with 5' 9" drivers and the Wooten fire box.

Engine No. 385 of the Philadelphia & Reading Ry. Co., a single driver, compound, hauled five cars from Wayne Junction to Bound Brook, a distance of 54.9 miles, at an average speed of 75 miles per hour.

On September 25, 1895, the New York Central & Hudson River Ry. Co. ran a newspaper train; consisting of two cars, from Albany to Syracuse, a distance of 147.84 miles, in 130 minutes, average 68.23 miles per hour.

An engine of the Delaware, Lackawanna & Western R. R. hauled a special train from Binghamton to East Buffalo, a distance of 197 miles, at the rate of 60.64 miles per hour.

We give herewith a recent performance of engine 1026 of the Atlantic City Railroad. This engine is of the same type of the C. B. & Q. engine 590, except that it has Vauclain compound cylinders, and Wooten fire box and standard fourwheeled truck. The train on these runs generally included two Pullman cars, but on May 29th and June 6th there were three, and on two other trips there was only one. On June 6th there were nine cars in the train and on June 10th there were but six, the latter being the lightest train hauled, the distance being 55½ miles.

1896.	Cars.	Left Camden.	Arrived Atlantic City.	Total time minutes.
May 29..........	7	4:10:45	5:03:45	53
May 30..........	7	4:11:30	5:03:30	52
June 1...........	6	4:10:40	5:01:40	51
June 2...........	6	4:11:00	5:02:00	51
June 3...........	6	4:11:00	5:03:30	52½
June 4...........	6	4:10:00	5:02:00	52
June 5...........	7	4:10:00	5:02:00	52
June 6...........	9	4:10:10	5:06:10	56
June 8...........	6	4:10:00	4:59:00	49
June 9...........	6	4:10:00	5:00:00	50
June 10..........	6	4:09:00	4:57:00	48
June 11..........	7	4:09:32	5:00:00	50½

The fastest regular trains in this country are run between New York and Philadelphia, and from Philadelphia to Atlantic City over the Philadelphia and Reading, Atlantic City railway and the Central Railway of New Jersey. These trains average about sixty miles per hour. The schedule time of the Empire State express is 53.33 miles per hour.

LONG DISTANCE RUNS.

The fastest long distance run on record was made October 24, 1895, over the Lake Shore & Michigan Southern railway from South Chicago to Buffalo, N. Y., a distance of 510.1 miles, at an average speed of 65.07 miles per hour, excluding stops. This run was made with five Brooks engines, engine No. 564 (shown on page 277) making the best record, covering 86 miles at an average speed of 72.92 miles per hour. The train consisted of two sleepers and a private car; total weight, 304,500 pounds.

On September 11, 1895, the New York Central & Hudson River Railroad company ran a train from New York to Buffalo, a distance of 436½ miles, in 407 minutes, an average of 64.22 miles per hour, exclusive of stops. Three engines were used, Nos. 999, 903 and 870; the two latter are 100-ton engines, and the 999 weighs 102 tons; the train weighed 361,000 pounds. Engine No. 903 made the best time, having covered 145.60 miles at an average of 65.75 miles per hour; this engine has 19x24 inch cylinders; drivers 78 inches in diameter.

The London & Northwestern railway and the Caledonian railway (West Coast Route) made a run on Aug. 22, 1895, from London to Aberdeen, a distance of 540 miles, at an average speed of 63.93 miles per hour, exclusive of stops. Four engines were used, engine No. 904 making the best record, covering 141.25 miles at an average speed of 67½ miles per hour; this engine has 17x24 inch cylinders, with 78-inch driving wheels; the weight of the train was 150,080 pounds.

The Delaware, Lackawanna & Western Railroad company ran a special train from Hoboken to East Buffalo, a distance of 404 miles, at an average speed of 50½ miles per hour, including stops.

December 29, 1893, a special train was run from Chicago to Atlanta, Ga., a distance of 733 miles, at an average speed of 45 miles per hour. The run was made over the Chicago & Eastern Illinois, Evansville & Terre Haute, Louisville & Nashville, Nashville, Chattanooga & St. Louis, and the Western Atlantic Railway, the best time being made on the Chicago & Eastern Illinois railway.

During December, 1893, new mail and express trains were put on the Chicago & Northwestern railway and the Chicago Burlington & Quincy railway between Chicago and Omaha; the distance over the Chicago & Northwestern railway is 490 miles, and over the Chicago, Burlington & Quincy, 499 miles. These trains run in competition, carrying the cars of rival express companies. On December 27, 1893, they reached Omaha, the

C. & N. W. Ry. beating the C., B. & Q. two minutes; both trains running into the Union Pacific Railway station at Council Bluffs, opposite Omaha. The time of the former was 11 hours and 23 minutes, or at the rate of 46 miles per hour, deducting stops. The Northwestern train carried one express car and two mail cars, while the Burlington train was composed of six cars, therefore the C. & N. W. had the advantage of both distance and weight.

On August 26, 1894, a special train was run from Jacksonville, Fla., to Washington, D. C., a distance of 780 miles, in 880 minutes, which is an average speed of 53.18 miles per hour; from Ashley Junction to Florence, a distance of 96 miles, the run was made in 99½ minutes, including two stops.

AIR BRAKE.*

Q.—1. What are the essential parts of the automatic air brake?

A.—The air pump, the main reservoir, the engineer's brake valve, the train pipe with its hose and couplings, the auxiliary reservoir, the triple valve, the brake cylinder, the gauge and pump governor.

Q.—2. What service does each of these parts perform?

A.—The air pump compresses the air for setting and releasing the brake; the main reservoir is used to store a supply of air for charging the train pipe and auxiliary reservoirs when empty, as well as to hold the supply for increasing the train pipe pressure when the brake is to be released, and charge the train pipe and auxiliaries to standard pressure ready for the next application; the brake valve controls the flow of air from the main reservoir to train pipe, from the train pipe to the atmosphere, or stops the passage of air through it in any direction. With the brake valve the brake can be set, either gradually or with full force; kept in that position, or released, according to the manner in which it is handled by the engineer. The train pipe with its hose and couplings extends from the brake valve and with suitable connections supplies each auxiliary reservoir with air for operating the brake. There is an auxiliary reservoir for each brake in which air is stored to operate that brake. The triple valve is connected to the train pipe, auxiliary reservoir and brake cylinder; it is used to control the charging of the auxiliary with air and regulate the time in which this is done, to open a valve to let air pass from auxiliary to brake cylinder to set the brake, or by another movement close this valve and open the exhaust valve so air can get out of brake cylinder to atmosphere and release the brake. The triple valve is operated by a variation of pressure in the train pipe, this variation is controlled by the brake

*This chapter was written by the acknowledged authority, Mr. Clinton B. Conger,

valve. The brake cylinder, with its piston connected to the brake levers, sets the brake when the triple valve lets air into it. The gauge shows with the red hand the pressure in the main reservoir, with the black hand the pressure in the brake valve over the equalizing piston and in brake valve reservoir; when brake valve is in full release or running position, it also shows the train pipe pressure. The single hand gauge used with the old style brake valve shows the pressure in train pipe only. The pump governor is located in the steam pipe to the pump; it is operated by air pressure and shuts off the steam to the pump when air pressure gets up to the standard pressure carried.

Q.—3. If any of these essential parts is broken or disabled, can the brake be set and released?

A.—That depends on what part is broken or disabled.

Q.—4. Name a part which if broken will prevent any brakes on train or engine being operated, also name a part which can be disabled on a car or engine and still let the brake be set and released on other cars?

A.—If the train pipe on the engine or the brake valve is broken off, none of the brakes can be operated from that engine after they once set. If anything is broken, that allows train pipe pressure to escape, and it cannot be repaired so train pipe pressure can be restored, none of the brakes can be operated. If train pipe on any car is broken, that car can be switched behind the others, and the others operated. If triple valve, auxiliary or brake cylinder is disabled, the cock can be closed so no air can get from train pipe to triple, and let all other brakes be operated.

Q.—5. How should the engine and tender air brake equipment be inspected before leaving the engine house to couple to a train?

A.—The air pump should be started at a moderate speed; the piston rod packing, valves and all joints in the piping examined to see that no air comes out through leaks. When the standard pressure is reached, the pump should be shut off by the governor; if there are no leaks the hands on air gauge should remain stationary. If there are no leaks, try the brake by reducing train line pressure from 70 to 50 and see that brake pistons have the proper travel and brake does not leak off. All the levers, brakes, beams, hangers, shoes and connections should be in good order, the reservoirs, drain cups and triple valves should be opened to see if there is any water in them, train pipe should be blown out through rear hose—with brake valve in full release—to be sure there is no dirt or obstruction in it.

Q.—6. How do you test for leaks in the brake valve? In the main reservoir? In train line? In air signal line?

A.—A leak in the brake valve to the outside air can generally be found by the sound. When the brake has been set tight, valve placed on lap and cut out cock under brake valve shut, a leak under rotary valve into or out of train line will soon show on black hand of gauge. Shut off the pump, place brake valve on lap, a leak in main reservoir line will show on red hand. Place valve on lap, a leak in train line will set the brake and black hand will drop back; with D-8 valve, the valve should be set half way between running position and lap, Shut the cut out cock next to reducing valve, a leak in signal line will make the whistle blow. Sometimes joints in the piping will leak when engine is in motion and be tight when standing still, or pipe may be worn through when it rubs against another pipe or a bolt. Jar the pipes a little to find such leaks.

Q.—7. What effect does water in the main reservoir have? In the auxiliary reservoir? How often should they be drained?

A.—The brake will not release as quickly, especially on a long train, as the main reservoir will not hold air enough to charge train pipe properly. If the auxiliary has water in it, the brake will not set as tight and release sooner. Both reservoirs should be drained often; the main reservoir every day in damp or snowy weather.

Q.—8. If the equalizing reservoir is broken off, or the pipe leading to it from brake valve broken, what is necessary to do?

A.—Make a blind joint where pipe is connected to brake valve, plug the train pipe exhaust elbow and use brake valve on direct application, taking care to make a gradual reduction so brake will not set with emergency, and closing valve slowly so the brakes on head end will not be "kicked off."

Q.—9. Explain about the excess pressure, why it is necessary, where it is stored, and whether more is needed for a long or short train.

A.—Excess pressure is the difference between main reservoir and train line pressure. The brake valve has a small valve in it, held on its seat by a spring strong enough to require about 20 pounds to raise it. When the brake valve is on "running position" the air has to go by this valve to get into train line, and that keeps a higher pressure in the main reservoir than we use in train line. With D-5 brake valve the excess is controlled somewhat differently, but its effect is the same. When the brake valve is put in full release, this excess pressure charges the train pipe quickly, forcing all the triple pistons into exhaust position at about the same instant and releasing the brakes with more certainty. It also furnishes a greater supply to charge the auxiliary reservoirs ready for the next application and for uncharged cars that may be taken on the train. It is always stored in the main reservoir, never any-

where else. Higher excess is needed for a long train than for a short one.

Q.—10. What is the proper auxiliary reservoir pressure?

A.—Seventy pounds on most roads; some have a little more, very few less than 70 pounds.

Q.—11. Is it safe to carry either more or less than this pressure?

A.—It is not safe to carry either more or less than the standard pressure for your road. If the leverage of the cars is properly adjusted to the standard pressure, it is all you can use without sliding some of the wheels; those wheels will hold very little in proportion to what they should. If too low a pressure is carried, the cars will not have enough brake power to make a proper stop in case of accident or sudden danger. Foreign cars in your train will not hold properly unless the standard pressure on that road is carried; this calls for a uniform pressure on all roads.

Q.—12. How do you know you have this amount?

A.—If the governor is set for the standard pressure and shuts off the pump when both hands on gauge show the proper amounts, it is pretty certain that you have it. With the old automatic or little brass valve, if placed on lap and gauge shows standard pressure, remaining there, it shows the train pipe and auxiliaries are equalized at that pressure and there are no leaks in the train line. With D-8 valve if it is set half way between running position and lap it closes the running position feed port, shutting off the air from main reservoir to train line, and leaving equalizing port open; if train line and auxiliaries have equalized, the black hand will be stationary at the pressure they contain. With D-5 valve in good order, when the red hand begins to separate from the black one, it shows that train line and auxiliaries are charged to the pressure at which the feed valve is set.

Q—13. How long should it take to charge an empty auxiliary reservoir to 70 pounds and equalize with the train line at that pressure, and what regulates this?

A.—About 2½ minutes, sometimes less, very often a little longer as the feed ports are not always the exact size and strainers free. The size of feed ports where air gets past triple piston regulates this.

Q.—14. How long does it take to charge the auxiliary from 50 to 70 pounds when brake is released and train line pressure kept up to 70 pounds?

A.—From 25 to 40 seconds, and you should wait 40 seconds after release if you wish to be sure you have full pressure for next application.

Q.—15. Can the auxiliary be charged unless the triple valve has moved into exhaust position?

A.—It can not, as exhaust port is opened before triple piston gets up far enough to uncover the feed port.

Q.—16. How do you set and release the automatic brake?

A.—Reducing the train pipe pressure sets the brake and restoring the original pressure releases it. The triple valve piston has the train pipe pressure on one side and auxiliary reservoir pressure on the other. When the train pipe pressure is reduced the auxiliary reservoir pressure forces the triple piston toward the lesser pressure; this pulls the air valve open and lets air from auxiliary to brake cylinder. As soon as the pressure in auxiliary is a little lower than in train pipe, the triple piston moves back, closes the air valve, which shuts off the flow of air from auxiliary to brake cylinder and does not move up far enough to open the exhaust port and release the brake. If a partial application is made, another reduction in the train pipe causes the triple valve to repeat the operation, setting the brake tighter each time more air goes from the auxiliary to brake cylinder, as the pressure per inch on brake piston increases. When the train pipe pressure is reduced lower than the auxiliary and brake cylinder will equalize at, the triple piston does not move back, air valve stays open, and brake is set "full on," or to its full power of a service application. If a very sudden reduction in train pipe pressure is made, the quick action triples set the brake with full force on the first application. To release the brake, the engineer restores the pressure in the train line. This gives a greater pressure on that side of the triple piston than the auxiliary has, the triple piston moves away from the greater pressure, opens the exhaust port and lets the air escape from the brake cylinder to the atmosphere.

Q.—17. Can the automatic brake be set by any one else than the engineer? Explain fully.

A.—The brake can be set from the train by opening the conductor's valve, or the angle cock at rear end of train; pulling the hose apart so air will escape from train pipe; or any break or bad leak anywhere in train pipe will set the brake. When train breaks in two between air cars, all air brakes on both parts of the train set instantly. A brake can be set on a car that has been set out from the train, by opening the angle cock to let air out of train pipe. In such a case the brake can be released by bleeding the auxiliary reservoir, or with the old style freight brake with plain triple, by turning the plug cock in triple valve to cut-out position. This bleeds the brake cylinder.

Q.—18. Are brakes on cars so arranged that a small leak in train pipe will not set the brake?

A.—There is a small groove about 3½ inches long in the brake cylinder, so that a small amount of air can get past the brake piston and not move it. If the air does not come into brake cylinder faster than it can get out, the brake will not set. This is called a leakage groove. There are none in driver brake cylinders.

Q.—19. How do you allow for this when setting the brake?

A.—By making a sufficient reduction in train line pressure at the first application so enough air will go into brake cylinder to move the piston past this leakage groove. This takes from 5 to 7 pounds reduction, and it is absolutely necessary to be sure the piston covers the groove, or brake will leak off and the amount of air used be wasted. Very light reductions at the first application are dangerous; it wastes the air in auxiliary reservoir.

Q.—20. How much do you reduce the train pipe pressure to set the brake tight and not waste any air?

A.—20 to 25 pounds from 70. When the brake is set tight, the air pressure in brake cylinder and auxiliary reservoir should equalize at about 50 pounds. That will leave 50 pounds on top of the triple piston. If the pressure on the train pipe side or under the triple piston is any less than 50 pounds, the piston will stay down and hold the air valve open. One pound less will hold it down just as well as any amount, so that all air let out of train pipe after these pressures have equalized, is wasted.

Q.—21. Why is it dangerous to set and release the brake several times in making one station stop?

A.—Because each time you release the brake you let out the air in the brake cylinder. As this air comes from the auxiliary reservoir, you reduce the pressure there each time. The first time it is set full on and released, the auxiliary pressure is reduced to 50 pounds; the second time it falls to 35 pounds, and when you finally want to stop there is not enough air in auxiliary to stop with. This habit is an old style one learned by straight air men, which won't work with automatic.

Q.—22. If necessary to release the brake and set it again at once, how do you do it?

A.—If the brake holds so strong that the train is about to stop before reaching the proper place, move the brake valve handle to full release for just an instant and then place it on lap. This will force a few, sometimes all the triples up into exhaust position, releasing the brake, and hold the train line pressure so near the auxiliary pressure, the brake will set at once with a slight reduction.

Q.—23. If the train pipe is charged to a much higher pressure than the auxiliary reservoir, can the brake be set with a light reduction of pressure in the train pipe, as it is done when train pipe and auxiliaries are equalized?

A.—No. The triple piston will not move down and pull the air valve open till the train line pressure is reduced below auxiliary pressure. For instance, if auxiliary pressure is 50 pounds and train line is charged from main reservoir to 90, you must reduce from 90 down to the auxiliary pressure before the triple gets a chance to act.

Q.—24. How do you test the brakes when first coupling on a train?

A.—Have the full standard pressure on engine in train line and main reservoir, after coupling hose and opening angle cocks so all cars will charge with air. Wait till this is done. After signal is given to do so, set the brake with a full service application and wait till all brakes are inspected in turn, beginning with first car from engine. After each brake is inspected to see that it works properly and the piston travel is correct, the signal should be given from the last car to release. Each brake should then be inspected to see that it releases properly and that there are no leaks from exhaust port. If pressure retainers are to be used, another test should be made for them.

Q.—25. What other tests are called for by the time card or instructions?

A.—A standing or terminal test should be made whenever cars are taken on or set off from the train, after a break in two, or replacing a bursted hose, as the wrong angle cocks may be left closed. A running test should be made a mile from railroad crossings and draw bridges.

Q.—26. What is necessary in order to have all brakes set at the same time, with same pressure on brake piston, and release with same increase of train line pressure?

A.—All piston travels should be the same, all auxiliaries charged to the same pressure, and all the triples in good order.

Q.—27. What is the proper piston travel, and how do you adjust it?

A.—Not less than 5 inches nor more than 6. It is adjusted by taking up the slack with the dead lever, or in some cases by the underneath connections. Piston travel should not exceed 8 inches on passenger and 9 inches on freight equipment. If less than 5 inches, the shoes will be too close to the wheels when brake is released, and with less than 3 inches the leakage grooves in brake cylinder will not be covered, in which case brake will leak off at once.

Q.—28. If piston travel is too long, how will it affect the action of that brake?

A.—If piston travel is too long, that brake will not set tight with the same reduction of train line pressure the others have; it will not hold as strong, as there will be less pressure on the brake piston. With a full application, it will release before the others do with a smaller increase of train line pressure.

Q.—29. What does the graduating valve do? Explain fully.

A.—The graduating valve is in the main air valve and fastened directly to the triple piston rod. It opens or closes with a slight movement of the triple piston, although the main air valve has to move to admit air to the brake cylinder. In its operation, when enough air has gone into the brake cylinder to reduce the auxiliary pressure a little lower than the train pipe pressure, the triple piston moves upward, closes graduating valve, but does not have force enough to move the main air valve, which would open the exhaust port and release the brake. Another reduction of train line pressure moves the piston down, opens the graduating valve again and admits more air to the cylinder. The graduating valve is designed to open and close with a very slight change of pressure on either side of triple piston. When pressure is great enough under triple, it moves the main valve, graduating valve and all.

Q.—30. If the graduating valve leaks, will the triple valve move to exhaust position before you want it to, with a partial application? With a full application? Why is this?

A.—Yes, with a partial application, because if it leaks the air will continue to go into brake cylinder and soon reduce the auxiliary pressure so train pipe pressure can move triple piston and valve to exhaust position. With a full application this does not take place, as air pressures are equalized and auxiliary pressure will not get below train line, although with leaky piston packing or joints, a leaking graduating valve will release brake with either partial or full application, as the leak will reduce auxiliary pressure below the train pipe pressure.

Q.—31. What difference between the plain and quick action triple valves?

A.—The plain triple valve has the cut-out cock in the body of the valve, the quick-action has it in the cross-over pipe between the train pipe and triple. The plain triple does not have the additional parts to work the emergency action of the triple, consequently the brake is not liable to leak on or off through the emergency valves or checks. The plain triple used on engine, tender and coach equipment is so arranged that the piston works perpendicularly, and when the train is running the jar may work it down and cover feed port, so a very light reduction will set it; the piston in quick-action triple moves

horizontally, so its weight does not influence the action of the triple when running. If plain triple is to be cut out, the brake must be released first, as cutting out at triple prevents the escape of air from brake cylinder. The brake with quick-action triple can be released by bleeding auxiliary, after it is cut out. No brake with quick-action triple can be set to work "straight air," as when cut out the brake cylinder is cut out from train pipe also.

Q.—32. Can both kinds be used on the same train with service application?

A.—Yes, if a moderately slow reduction of train line pressure is made at the brake valve.

Q.—33. How much pressure on the brake piston do you get on full application with plain triple valve, having 70 pounds auxiliary pressure and 8 inches piston travel?

A.—Fifty pounds, and you can get this with a number of light reductions added together, or at one reduction, if it amounts to 20 pounds or two-sevenths of the auxiliary pressure.

Q.—34. How much pressure on the brake piston with the quick-action triple valve and emergency application?

A.—Sixty pounds. With the emergency you will get the full pressure at the first reduction, provided it is sudden enough to operate the quick-action part of the triple. If you want the full pressure of 60 pounds, get it at the first reduction, or you may not get any more than 50 pounds.

Q.—35. Why this difference in pressure on brake piston?

A.—The brake with plain triple gets all its air from auxiliary, and can only have 50 pounds, while the brake with quick-action triple gets some air from the train pipe. When the emergency valves in triple open and let air out of the train pipe so as to make the next triple work quick-action, this air goes into the brake cylinder through a large port, equalizes in an instant, the air from auxiliary continues to flow in afterward through a small port in air valve, and the final pressure on brake is 60 pounds.

Q.—36. Does it take a sudden reduction of train pipe pressure to set the brake with the emergency action, or will a slow and heavy reduction set it with emergency action?

A.—A sudden reduction must be made and extend to the first quick-action triple to set them all with emergency. If the reduction is so gradual when it affects the triple that the graduating valve can let air into brake cylinder and reduce auxiliary pressure as fast as train pipe pressure is reduced, it will not work the emergency on the train. To show how light a reduction will operate the quick-action provided it is sudden, shut the angle cocks next to a quick-action triple valve, let the air out of hose, couple them up again and open angle-cock

suddenly. Just what air goes into the two empty hose from rear end of train will work the quick-action. If this angle-cock is opened very slowly, it will not do it.

Q.—37. What air pressure operates the pump governor, the train pipe or main reservoir?

A.—With D-5 brake valve, the main reservoir; with all others, the train pipe pressure.

Q.—38. If the governor does not regulate the train line pressure, how do you adjust it with D-8 valve? With D-5 valve?

A.—With D-8 valve the train line pressure is regulated by the pump governor. The spring in governor should be set so 70 pounds air pressure will raise the diaphragm and air valve, so air will go down on piston and force steam valve shut. If anything gets on the seat of this little air valve so it does not set tight, air will get through steady and keep governor shut off at a low pressure. With D-5 valve the train line pressure is regulated by the feed valve or train line governor on the side of brake valve. Set the spring in feed valve so it will let the train line pressure move feed valve piston down with 70 pounds pressure. This will let feed valve close, so no more air can pass from main reservoir through running position port to train line, and pump governor should be set at enough higher pressure to carry the desired excess pressure.

Q.—39. How can you tell if all the cars in your train are cut in and working air?

A.—I do not think any man can tell while in the cab if all the cars are cut in and working air, if you mean by that, all the brakes working. You can tell by the train line exhaust from brake valve if you have a long or short train, but that only gives you an estimate of the length of the train pipe, not the number of triples working; for if all the triples were cut out in the cross-over pipes, just about as much air would come out of the train line exhaust as with all of them cut in. Some men claim that they can tell when they release the brakes how many are working, as the main reservoir will drop a certain amount for each car—if a pound for each car, a drop of five pounds would mean five cars. The size of the main reservoir, speed at which pump was running, length and size of train pipe on each car, size of auxiliary, whether for 10-inch or 14-inch cylinder, and piston travel of various brakes, all would affect the amount of air it would take to charge up again. Possibly it can be done; some men claim they can do it on the train they handle every day.

Q.—40. Can you tell by the action of the brake valve if angle cock has been closed near the head end of train? How?

A.—Yes, sir. If the angle cock has been closed at or near the tender, the train line will be so short that when brake valve is put on full release or running position after making a service application, it will charge up quicker than cavity D, over equalizing piston. Then the train line pressure will raise the piston and air will blow out of train line exhaust till pressures equalize on either side of the piston. If the piston sticks or leaks very much this action will not always take place; the valve must be in good order. It is worth while observing this action in the D-8 and D-5 valves, as they give you notice when releasing brake than an angle cock is shut, and you will be unable to set brakes behind closed cock. A partial stoppage in pipe under tender will produce the same effect, or if the tender is piped with small pipe a very little air will blow out each time. Emergency application with D-8 valve does not show this effect.

Q.—41. If the train breaks in two between air brake cars, what should you do? Explain fully.

A.—Shut off the engine, lap the brake valve to save main reservoir air, whistle out a flag, have the open angle cock on the last car that is still connected to engine shut, let off brakes on the head part from engine. After coupling the parts of train together, test the brakes to see that all are working. Some men think that if all brakes release, that is test enough. Don't risk it.

Q.—42. If a hose bursts while the train is running, what should you do? How will you locate the bursted hose?

A.—If a hose bursts do about the same as in case of a train breaking in two. When the brakeman starts to find the bursted hose put your brake valve on running position, and let a little air back in the train line and hose so he can hear it blowing out when he comes to it. He should then shut the cock between bursted hose and engine. As soon as he does this, the black hand will begin to rise and knowing the escape of air has been stopped, can go to full release and let off brakes. After hose is replaced, brake can be released on the rest of the train. If it is not expedient to remain there to replace the hose, bleed all the cars behind the bursted hose and proceed, with all the train men understanding that you have only part of the brakes working.

Q.—43. Is it necessary to make what is called a terminal station test after breaking in two, or bursting and replacing a hose, before starting out with train again?

A.—I think so. Some think that if the brakes on rear cars are released by the engineer that is test enough, but it should be known that the brake can be set as well as released from

the engine. If you try to make up the lost time a good brake will be needed; better be sure.

Q.—44. If anything breaks about the brake rigging, can you operate that brake? What do you do in this case for both plain and quick action triples?

A.—No, sir. It will be necessary to cut out that brake and let the air pass through the train pipe to and from the other cars. This is done by turning the plug cock in the plain triple to a half way position between horizontal and perpendicular, so as to blind the ports that are next to and in line with the train pipe and brake cylinder connections; this will prevent this triple operating and cut out the brake cylinder so no air can get in or out. Be sure the brake is fully released before you cut it out. With the quick action triple shut the cut-out cock in cross-over pipe by turning handle parallel with pipe, and bleed auxiliary.

Q.—45. How should you set and release the brake on a "part air" freight train? How on a passenger train?

A.—Make a very mild reduction, between four and six pounds, and wait long enough for the brakes to take hold and slack up train, to run up against air braked cars before you make a second application or a third. After the train is bunched up solid, set the brake as tight as necessary to control the train. If you think hand brakes are set on rear end of train, give train men time to release them before releasing air brake and working steam. At a stop the air brake should be held on till train stops, to avoid breaking in two. With a passenger train make the first reduction about five to seven pounds, to be sure you cover the leakage grooves; very light reduction after the first one. When about to stop let off the brake a few feet before the final stop is made, so as to prevent the cars giving a lurch forward and then back; caused by the track tilting forward and then righting itself.

Q.—46. How does the pressure retainer operate? Explain fully.

A.—When the pressure retainer operates, it closes the opening through which the air escapes direct from the triple exhaust and holds part of it in the brake cylinder. To set it to operate, the handle is turned up horizontal or cross-wise of the retainer; this closes the direct opening to atmosphere and the air must pass out under a weighted valve. When pressure falls to fifteen pounds this valve shuts off the escape altogether and holds the air in there, keeping the brake set at fifteen pounds. The retainer when operating also checks the escape of the air till it gets down to this fifteen pounds, by causing it to pass out slowly from the shell or case of retainer through a very small hole, and gives the engineer a chance to recharge auxiliary

to standard pressure, ready for another full application. The retainer is placed where it can be reached easily when train is in motion, and has a pipe connecting it to exhaust port of triple. If this pipe is broken off or leaks badly the retainer can not be used, but that does not affect the operation of the other part of the brake.

Q.—47. Which engineer should handle the brake with a double header, and what should the other engineer do? If there is no cut-out cock in train pipe under the brake valve, what must be done? If it is necessary to help the engineer who is handling the air let off the brake, how should it be done?

A.—The head engineer, as he is the only man who can see all the signals and is the only man who can properly control the train. The other engineer must cut out his brake valve by closing the cock in train pipe near brake valve, carry valve on running position and a full supply of air. If there is no cut-out cock, place valve on lap, and plug train line exhaust elbow so air will not escape there when head engineer charges train pipe to release brake. If necessary to help head man let off brake and recharge auxiliary, open cut out cock and place valve on full release, taking care to close cut-out cock again as soon as train begins to move, so head engineer can set the brake if he gets a signal to stop; with your cut-out open he can not set brake.

Q.—48. Explain the operation of the air signal.

A.—The air signal has a separate line of train pipe and hose couplings connecting all the cars with the engine, but the hose couplings are made so they cannot be coupled into the air brake couplings. There is a reducing valve on the engine that takes air from the main reservoir line to charge this train signal line; also a valve, which, when operated blows the signal whistle in cab. On each car and connected to signal line is a car discharge valve. When it is opened the train signal pipe pressure is suddenly reduced. This operates the signal valve on engine in much the same way a triple piston or equalizing piston is moved, except that the signal valve has an air-tight rubber diaphragm instead of a metallic piston. A sudden reduction of pressure at this diaphragm raises it up, opening valve to whistle. When car discharge valve is closed the reducing valve recharges signal line to standard pressure ready for another operation. If signal line does not charge to standard pressure and all valves seat before another blast from car discharge valve, the signals will not be distinct and accurate. Standard pressure is about 40 pounds.

Q.—49. If signal whistle blows each time the engineer releases the brake, what is the trouble and how remedied?

A.—If the signal whistle blows each time the brake is released it is a sign that reducing valve on engine is stuck open and you have full main reservoir pressure in signal hose, which is liable to burst it; besides the signals are not accurate. Clean out the reducing valve to remedy this trouble. Where the signal valve is fastened to run board under seat box, slamming the cover of the box down hard will sometimes jar valve off its seat and give one blast of whistle. In cold weather if reducing valve freezes in its seat the whistle will generally blow one blast. Any leak in air signal line is liable to operate the signal and give the wrong signals. Train signal line should be entirely free from leaks.

Q.—50. Does skillful braking not require as good judgment as making a good record for handling a train in other ways?

A.—Yes, sir. It requires a great deal of skill to do good braking under all circumstances. Good judgment is needed to decide just how tight to set the brake to stop. The condition of rail, grade at stopping places, speed of train, holding power of brakes and all other conditions must be considered in the few seconds it takes to make a stop.

PISTON TRAVEL.

Probably no part of the air brake apparatus has had as little attention as the piston travel; at the same time it is most important that the piston travel should be uniform. Without a uniform piston travel it is impossible to have an equal distribution of braking force, so essential. Not only that, but also a simultaneous release of brakes, as the brakes with the short piston travel equalize at a higher pressure, causing some brakes to "stick" in a long train (or in a short one, should the main reservoir be under the proper capacity). Then again, there is the heating of wheels, where braking force is unequally distributed, due to the variation of piston travel, and this evil does not exist in the mind of the writer only, for it is obvious that when a 10 pound reduction is made in the train line pressure, the pressure in a 10″ brake cylinder with an 8″ travel is 22 pounds per square inch, against 44 pounds per square inch where the piston travel is 5″, a difference of 100 per cent.

In arresting the momentum of a train, there is a certain amount of friction applied to the periphery of the wheels by pressing the brake shoe against it. The braking that one car is shirking must certainly be done by the other. This, of course, means that the brakes are held applied longer, caus-

ing the shoes on them (the ones with the short piston travel) to heat. When this is done to any extent, such as on grades, and especially in cold weather, it is liable to cause cast wheels to crack, steel ones to loosen their tires, and no doubt a large amount of "shelling out" can be attributed to this same cause.

I personally know of an instance where a freight train made a stop for a side track, after which it went on the same, to allow a passenger train to pass. In making the stop the brake shoes on one of the cars got so warm as to melt the snow that had gathered around the shoe and then froze the shoe to the wheel, causing the wheels to slide.

In emergency cases we have to contend with the shocks produced by this same evil, the results of which are well known to the Master Car Builder and Claim Agent, to say nothing of the time that would have been saved had the piston travel been maintained at its highest efficiency, and to stop the cars is certainly the cardinal reason for placing the air brake on them. In case it should be necessary to "back up" in order to avoid a collision, we have to contend with the brake "sticking." We have a case on record where a train ran 640 feet after the brakes were applied, and had the train stopped 45 feet short of that distance there would have been a saving of twelve lives and enough money to place the air brake equipment in first class condition on the entire road.

In the report of the Railway Commissioners they say: "Seldom has the importance of having a train supplied with the best and most efficient brake been more terribly or more forcibly illustrated." (See Mass. R. R. Com. Report, 90.) Little would I be surprised to see a railroad held for criminal negligence in a case like this.

It occurs to me that if the brakes were put in more perfect order the engineers could better handle them. In going through the different yards you can find brakes in most any condition imaginable, from a light foundation gear to a 12″ piston travel, but that is not to be wondered at when we take into consideration that a prominent car company has their braking power varying from 40 per cent to 101 per cent. As long as such a state of affairs exists we should not lay the blame of "skidding" wheels at the door of the engineer.

Here we have a train of seven cars—say three are sleepers—the train starts out, the engineer finds that the brakes are not "holding;" he does the best he can until he comes to a car repairer's station. He says to him, "These brakes are not holding." The car repairer, of course, starts at the baggage car, pulls the dead lever back—this is easy—and continues until he comes to the sleepers. There he must use a wrench and turn the turn-buckle—which is not so easy—and with these,

besides the four cars he has operated on, he has done his work well. The train is ready to go on, and what is the use of holding it any longer? The train proceeds; the engineer finds his brakes not much better, but gets in after going by several times. Next day he finds out that they were "sliding" wheels on his train, then he commences to think about "two applications" and other things, when, in fact, he is not to blame at all. Only the other day I noticed a good deal of shoe clearance on a sleeper, and decided to measure the piston travel; so I waited until the brakes were being tested, then I measured the piston travel and found it 10". The car was starting on a 640 mile trip, and the inspector told me that no one dared touch the car en route.

Most railroads have rules requiring the piston travel to be maintained within a fixed limit, but it takes something else besides rules to adjust piston travel, and frequently the inspectors haven't the time to make the proper adjustment.

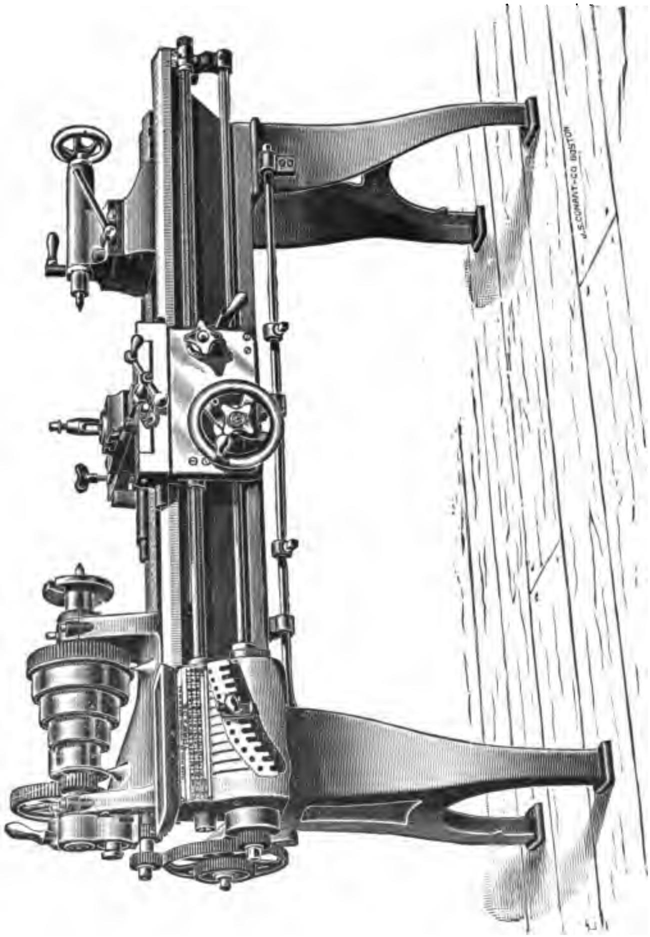
IMPROVED TOOLS.

THE HENDLEY-NORTON LATHE.

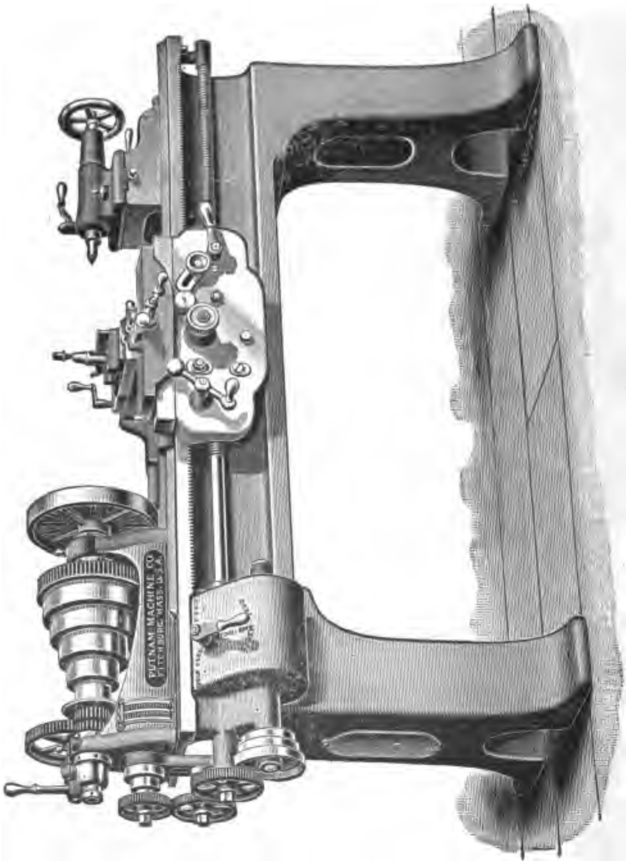
This illustration shows the Hendley-Norton lathe, which combines most of the latest improvements upon modern lathes, and is noted for rapid work. They are built in three sizes, viz.: 4, 5 and 6 foot beds. The main feature of this lathe is its gears; by means of the Norton attachment for screw cutting 12 different threads or feeds can be secured without change of gears, the movement of lever in the gear box (shown at the left) from one notch to the other being all that is required. These embrace all the threads that are in ordinary use, also 36 different threads or feeds are obtained with but two changes of gears and movement of lever in gear box from notch to notch. A convenient reversing device, operated by a handle from the apron, is used for all feeds and screw cutting, allowing the spindle to run continuously in one direction—a saving of belts, power and time. It also allows the use of two straight belts on the counter-shaft, giving 16 spindle speeds, two with lathe in motion, or 16 in all. It has an improved automatic stop. It automatically stops the carriage when feeding or in thread cutting, in either direction, obviating all danger of running into shoulders in turning or thread cutting or bottom of holes in boring out internal work, which is especially valuable in duplicating pieces, it being necessary to make but one measurement. It also has an improved taper attachment on the back of the bed. All these lathes (except the Rise and Fall or Double Carriage lathe) have interchangeable tool rests, each lathe being arranged to take one or all of four rests—a plain rest with a shoe; a patent vertical, elevating by means of a screw; an improved quick elevating; and a compound rest.

ENGLISH AND METRIC SCREW CUTTING LATHE.

This illustration is of a thoroughly modern engine lathe. It is a lathe of the conventional form, embracing most of the modern improvements, and is a well known Pond tool. The special feature of this lathe is its gears for thread cutting, viz.,



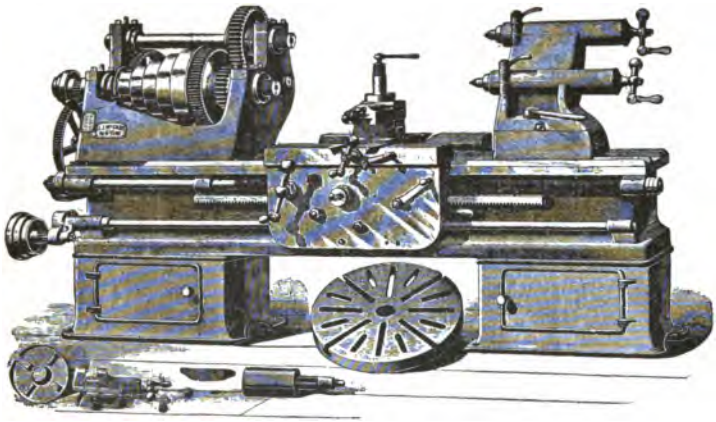
THE HENDLEY-NORTON LATHE.



ENGLISH AND METRIC LATHE.

it is geared to cut both English and Metric threads. The screw works and feed motions are new. The former will cut in English from 4 to 36 threads to the inch, including 11 ½″ standard pipe thread, and by simply changing the position of the translating handle in the hood (shown on the left) the same results are given in the Metric system.

A DOUBLE SPINDLE LATHE.

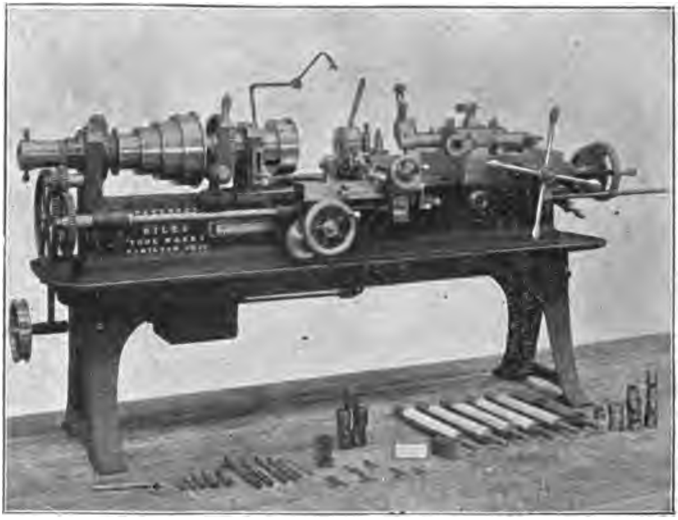


This lathe is not intended or expected to take the place of a large lathe on heavy work, but for small shops, where only one or two lathes are used, it will practically take the place of a larger lathe, and yet not be too large for the average work. When a pulley or similar piece of work is to be turned, the compound spindle expedient seems to best meet the circumstances. It is a recent improvement.

THE NILES SCREW MACHINE.

This cut shows the well known Niles screw machine, a modern tool with which most railroad machinists are thoroughly familiar. It is especially adapted to locomotive work and differs only slightly from the various other forms of screw machines. The lead screw does not extend to the end of the machine, but is short and heavy and is socketed into a shaft

which runs to the end of the machine and is driven by gearing; the lead screw is thus a plain shaft with short arms, removable threaded end. The gearing is never changed. Different lead screws are used for different threads; they are easily changed, and the adjustable lead screw nut is double ended, so that each nut will do for two pitches.

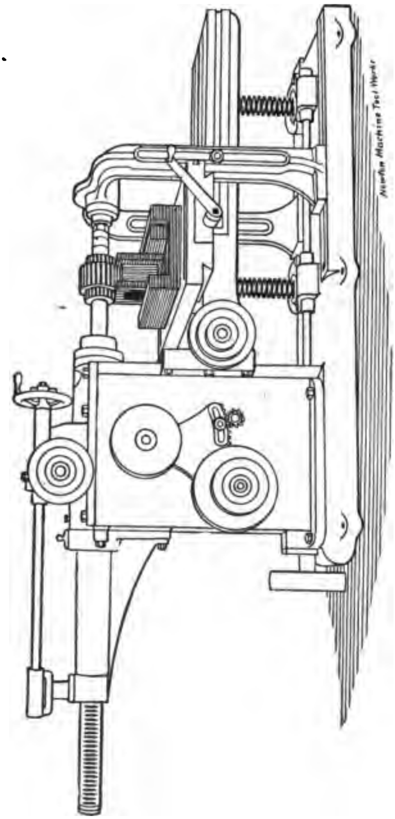


A MODERN SCREW MACHINE.

HORIZONTAL BORING AND MILLING MACHINE.

We have shown a view of the new combined boring and milling machine, made by the Newton Machine Tool Works, at Philadelphia. There has been a demand in railroad shops especially for a heavy boring machine that could be converted into a milling machine without being complicated or troublesome to change. As a rule combined machines are very expensive, and some of the important points are sacrificed to produce the combination. As can be seen by the accompanying illustration, this machine can be changed almost instantly from a boring to a milling machine without being at all complicated. The boring bar of the machine is 4¼ inches in

diameter and has an automatic feed of 42 inches. The knee, as shown in illustration, is 6 feet long. The machine will bore to the center of 65 inches over the carriage. While the general

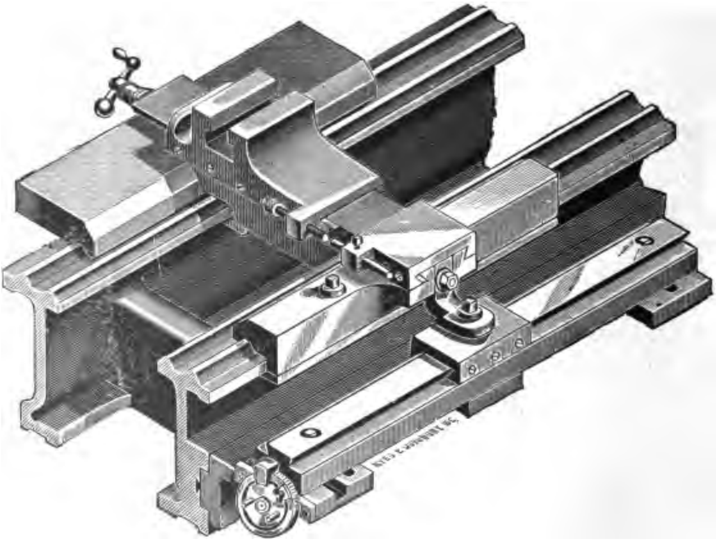


COMBINATION BORING AND MILLING MACHINE.

outline of the average horizontal boring machine is carried out, the driving and feed mechanism is entirely different. On the sleeve that drives the boring bar is a phosphor-bronze triple-lead worm wheel, and driving this is a hardened steel worm wheel, which has combination thrust collars of phosphor-bronze

and hardened steel on each end. The driving cone pulleys and back gear are on the side of the worm shaft. By this combination the machine has about double the power of the average horizontal boring machine of the same capacity. The feed pulley on the end of the worm shaft is belted to the cone pulley on the quadrant, and another belt is used on the top cone pulley for feeding the bar. When required to be used as a milling machine, it is only necessary to change the belt on feed cone pulley on the knee and adjust the proper tension with the quadrant.

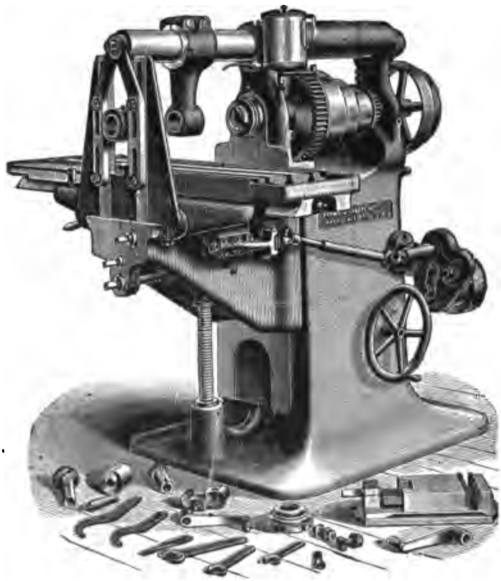
FLATHER TAPER ATTACHMENT.



This cut shows the construction of the Flather taper attachment, which was patented in November, 1893. It will be interesting to those who are not familiar with a taper attachment; it will turn a correct taper either internally or externally. All movements and adjustments can be made by the operator in front of the lathe; the bar is set by a graduated disc provided with stops, while the depth gauge stop is shown on the side.

UNIVERSAL MILLING MACHINE.

This cut shows one of Brown & Sharpe's well-known milling machines. This is a very stiff, strong machine, well adapted to the class of work done in locomotive shops. This machine is of the latest design and presents a number of new features, principally in connection with the feed. The table is fed at an

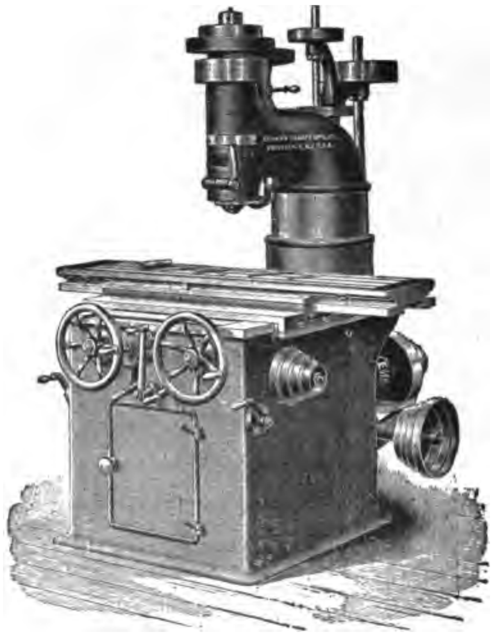


angle to the axis of the spindle, and there is a provision for automatically cutting spirals. The table has an automatic longitudinal feed of 25 inches, a traverse movement of 7½ inches and can be lowered to 18½ inches from center of spindle. The centers swing 12 inches in diameter and 21 inches in length. It has a three-step cone with six feeds.

VERTICAL SPINDLE MILLING MACHINE.

This type of machine for many kinds of work is preferable to a machine with a horizontal spindle, as the operator can

more easily see the work and more readily follow any irregularity in the outline of the surface to be milled. This is a very plain type of milling machine, and a great many of them are in use in railroad shops. This machine has a longitudinal feed of 41″ and a traverse feed of 12″—greatest distance from end of spindle to table 15″—and it is provided with a universal chuck.

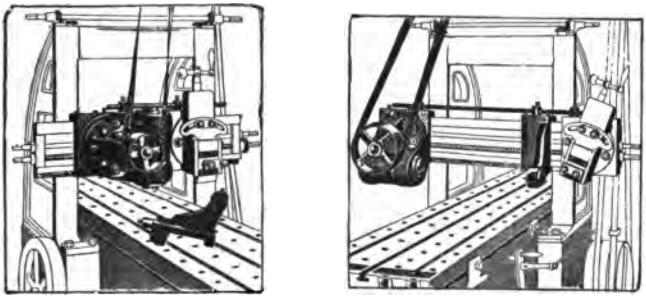


VERTICAL MILLING MACHINE.

FARWELL'S MILLING ATTACHMENT.

While much prejudice exists against combination tools, yet, owing to the simplicity of this device, and the large range of work it is capable of performing with so few tools, we believe it deserves especial notice. The two small views shown explain themselves. This device may be attached to any planer, and

as may be seen the spindle is capable of either a horizontal, vertical, or angular adjustment. With two spindles to the counter-shaft and three sizes of pulleys to change on the worm shaft, gives six speeds to the spindle.



FARWELL'S MILLING ATTACHMENT.

CRANK SHAPER.

The accompanying cut shows an improved crank shaper. The cross and down screw feed screws are graduated to thousandths. The head is also graduated for angular work. Another convenient improvement upon this tool is the open space under the ram, through which to pass shafts for key seating.

IMPROVED SLOTTING MACHINE.

This cut shows an up-to-date slotting machine, especially adapted for all kinds of locomotive work. Its stability, power and convenience are the main features. It has a stroke of 14" and will take work 78" in diameter. The table being 30" in

diameter, with 28" longitudinal, and 22" transverse traverse, the tables have compound feed in either direction; the cutter bar is operated by means of the Whitworth quick return movement, and the driving cone has four steps for 4" belt, making it a very powerful as well as convenient tool.

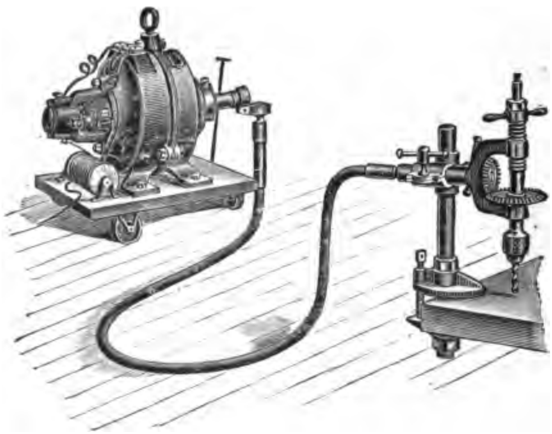
THE YANKEE TWIST DRILL GRINDER.

This cut shows a very simple and convenient tool for any machine shop, which any one can operate, and when the drill

is finished it will have the proper clearance and an angle of 59 degrees (which is the angle given when manufactured). The adjustment for drills of various diameters is obtained by an ingenious and simple combination of angles in the sliding holder, and it will grind any size drill from ⅛″ to 2 ¼″.

ELECTRIC MOTOR DRIVEN TOOLS.

From present indications we believe it will be only a few years until all the machines in our large railroad shops will be driven by electric motors instead of a line shaft as at pres-



ent. Already the Baldwin Locomotive Works use electric motors that aggregate 250 horsepower, and many of our large shops use motors for driving independent machines. It is claimed the motors save fifty per cent of the total cost for power.

THE END.

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